

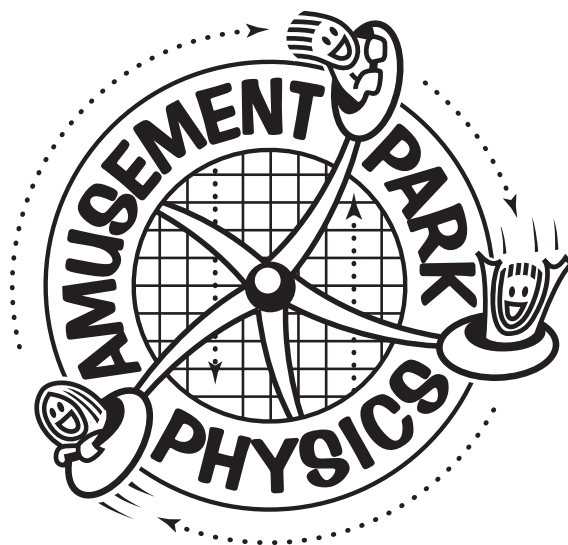
Amusement Park **PHYSICS**



PLAY
LaNd
At the PNE
Vancouver

PHYSICS and
SCIENCE DAY
2015

Physics 11/12



These educational materials were created by *Science Plus*.
Illustrations, typesetting and layout by
Robert Browne Graphics.

For more information on Amusement Park Science
contact Jim Wiese at jim.wiese@shaw.ca

Vancouver, B.C., Canada
March 2015

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Amusement Park Physics

It's hard to believe that *Amusement Park Physics* at Playland is celebrating its **28th anniversary** this year. The project was started in 1988 with our senior Physics students and was expanded in 1990 with the addition of the Grade 9 program. Later we added an elementary school version *The Science of Fun*. In 2008 we added a French Version for elementary schools called *La Science du Plaisir* and a curriculum for Grade 8 Science and Grade 10 Science. In 2011 we added a version for Biology 12, and in 2012 we added a version for students in Chemistry 11 and 12. A special thanks goes to Steve Simms and Mike Eckert at Clayton Heights Secondary for helping with the new Chemistry module. The purpose of *Amusement Park Physics* is to provide students with practice in applying to real situations some of the concepts learned in the classroom study of mechanics. It has been an enjoyable conclusion to that aspect of the curriculum and can assist in preparation for final examinations.

With the involvement of students from other schools and other districts, the project serves to bring together teachers and students to share their common interest in science. We welcome your participation in either or both events.

Due to the success of *Amusement Park Physics*, we have spread the events to five days in the spring and one day in the fall. You may choose any of these days but we will be limiting numbers to 2500 students per day. These will be filled on a first come basis. This should help eliminate any lineup at the rides to let students make measurements multiple times on each ride.

There is a curriculum package for each grade level – Science 8, Science 10, Physics 11/12 and Biology 12. You need to only download and print the version that you need. Please feel free to adapt any materials to better suit your students.

I'd like to thank all those involved in *Amusement Park Physics 2015*: Michelle Pattison, Steven Simms, Jennifer Campbell, Peter Male and the staff of the Pacific National Exhibition and Playland for their support. The work and dedication of all these people make *Amusement Park Physics 2015* possible.

Jim Wiese

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Introduction

The accompanying materials have been divided into several sections: one with information concerning measurements, one containing information on instrument construction, and one with the ride worksheets for Physics 11 and Physics 12, and one with make-up assignments. Teachers are given flexibility for its use but are reminded that this educational program is used by many schools.

We try to have consistency between schools' implementation by asking each teacher to remind their students that this is an educational event. A rule of thumb is to have each student or group of students complete 3 or 4 of the modules. That is a reasonable expectation for them and keeps them on task during the day. Schools that are wishing to use this event as a reward for "hard work" through the year and that do not intend to have their students working on this material are asked to make arrangements to visit Playland at another time.

This year's curriculum reflects the different demands that are placed on students in Science 8, Science 10, Physics 11 and Physics 12. This has hopefully brought it more in line with Provincial Ministry Physics guidelines and the Physics 12 Provincial Examination.

Students must be using the following materials throughout the day:

1. Packet of activities
2. Pencil
3. Timing devices (digital watches with stopwatch mode are nice)
4. Vertical and lateral accelerometers (see packet for details – make arrangements for sharing between students if supply is short). Each school is responsible for providing their own accelerometers.
5. Calculator

Critical Safety Note

Any instrument or devices carried on rides by students should be made of plastic and provided with some kind of wrist tether, so that if dropped, the instrument will not break or fall off the ride and cause injury or damage.

Sample Timetable

Please adapt to fit your circumstances

Time Schedule

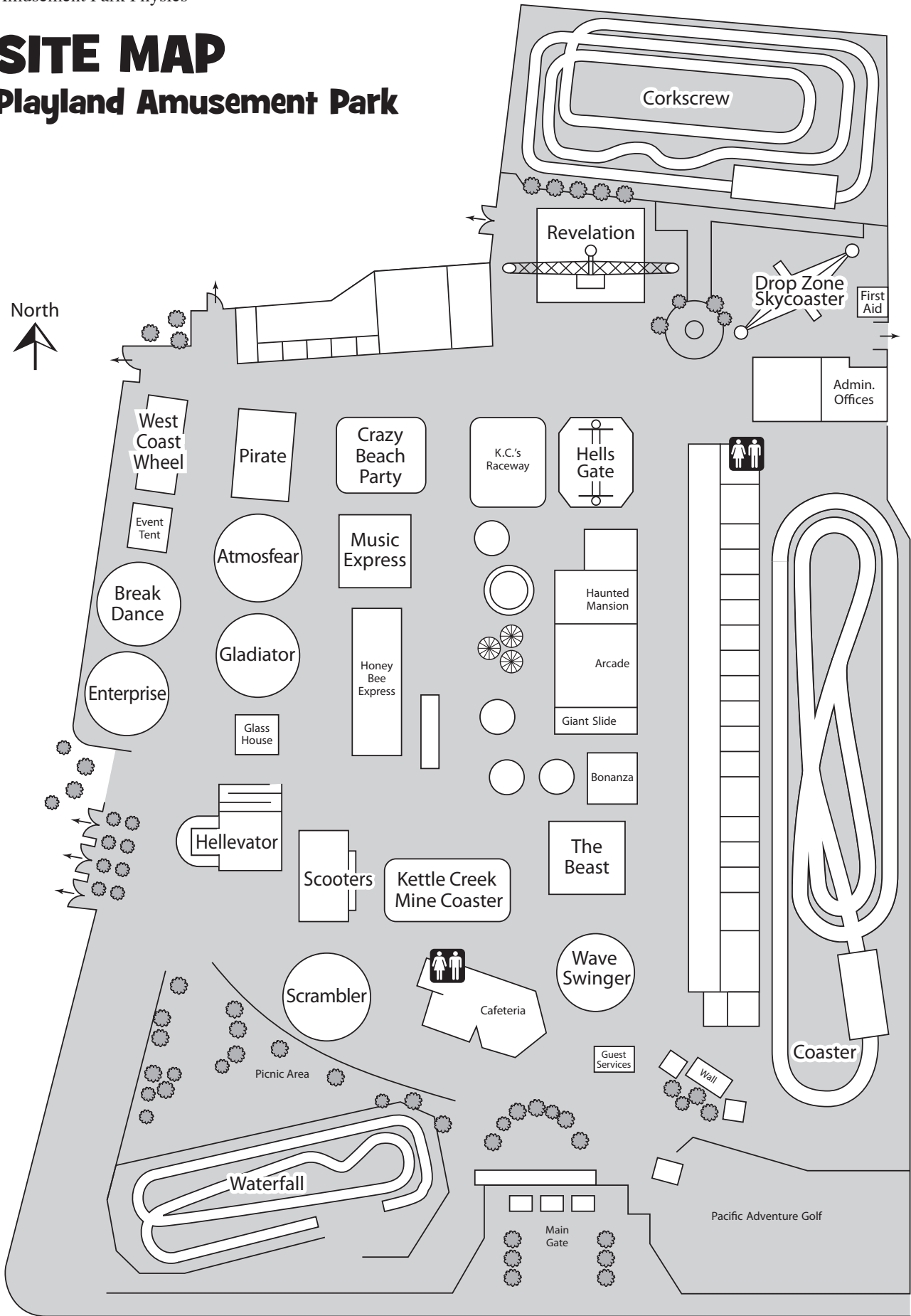
8:30	Buses leave school
9:15	Arrive at Playland
9:30	Enter Exhibition Bowl for opening session
9:45 – 10:00	Opening Presentation at Exhibition Bowl
10:00	Gates to Playland open to admit students
10:00 – 2:00	Carry out pre-planned activities involving observations and measurements of selected aspects of the rides. Arrange a meeting time with your teacher for problems that arise or questions you have.
2:00	Playland closes and event ends
2:15	Board buses for return to school
3:00	Buses arrive back at school

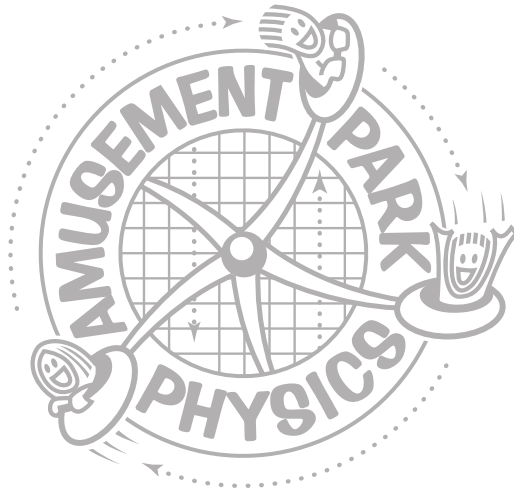
Things to Bring:

- ☐ BRING A LUNCH (You will NOT be allowed to leave the park for lunch)
- ☐ BRING A PENCIL
- ☐ Bring a calculator if you wish
- ☐ Don't forget to bring this assignment package!
- ☐ Try to bring a watch with a second hand or digital seconds to record times on the rides. A digital watch with a stopwatch mode works very well.
- ☐ Try to return all equipment (dropper bottles, chemicals, etc.) to your teacher when you are not using them during the day. You'll be sharing them with other students and we need to make sure everyone gets a chance to use them.

SITE MAP

Playland Amusement Park





Section A

Making Measurements

page A-1	Time
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Time

The times that are required to work out the problems can easily be measured by using a watch with a second hand or a digital watch with a stop watch mode. When measuring the period of a ride that involves harmonic or circular motion, measure the time for several repetitions of the motion. This will give a better estimate of the period of motion than just measuring one repetition. You may want to measure the time two or three times and then average them.

Distance

Since you cannot interfere with the normal operation of the rides, you will not be able to directly measure heights, diameters, etc. All but a few of the distances can be measured remotely using the following methods. They will give you a reasonable estimate. Try to keep consistent units, i.e. meters, centimeters, etc., to make calculations easier.

Pacing: Determine the length of your stride by walking at your normal rate over a measured distance. Divide the distance by the number of steps and you can get the average distance per step. Knowing this, you can pace off horizontal distances.

My pace = _____ m

Ride Structure: Distance estimates can be made by noting regularities in the structure of the ride. For example, tracks may have regularly spaced cross-members as shown in *figure a*. The distance d can be estimated, and by counting the number of cross members, distances along the track can be determined. This method can be used for both vertical and horizontal distances.

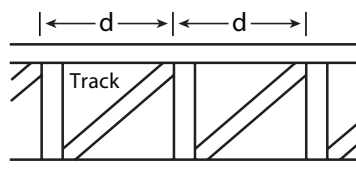


figure a

Triangulation: For measuring height by triangulation, an astrolab such as that shown in *figure b* can be constructed.

Practice this with the school flagpole before you come to Playland.

Suppose the height h_r of the **Roller Coaster** must be determined.

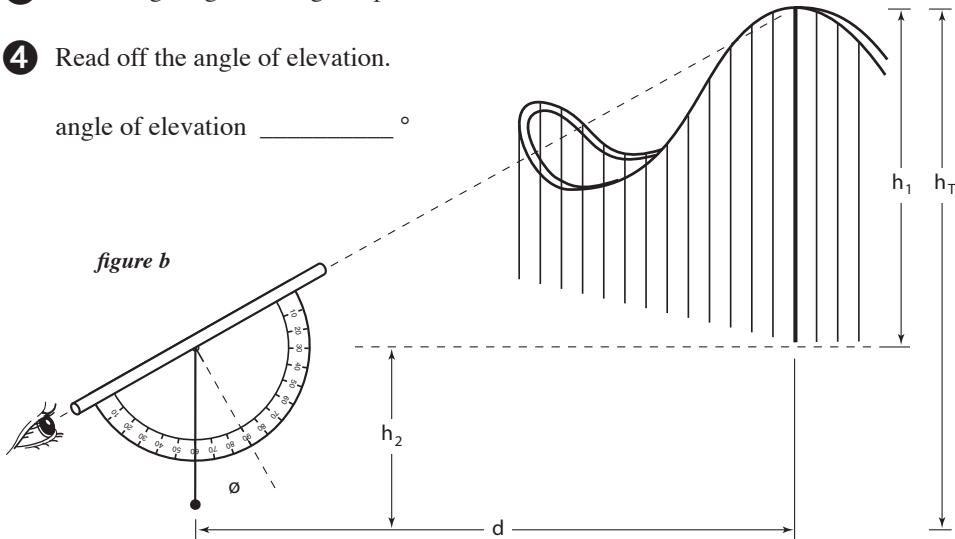
- 1 Measure the distance between you and the ride. You can pace off the distance.

distance d = _____ m

- 2 Measure the height of the string hole.

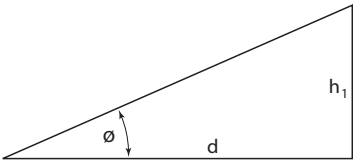
string hole height h_2 : h_2 = _____ m

- 3 Take a sighting at the highest point of the ride.
- 4 Read off the angle of elevation.



Then since $h_1/d = \tan \theta$
 $h_1 = d (\tan \theta)$

- 5 Look up the tangent value for the angle measured:
- tangent value: _____

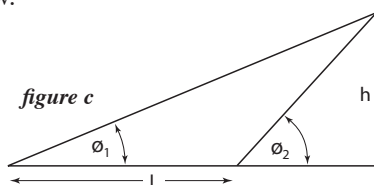


angle	tangent	angle	tangent	angle	tangent
0°	.00	30°	.58	60°	1.73
5°	.09	35°	.70	65°	2.14
10°	.18	40°	.84	70°	2.75
15°	.27	45°	1.00	75°	3.73
20°	.36	50°	1.19	80°	5.67
25°	.47	55°	1.43	85°	11.43

- 6 Multiply this tangent value by the distance from the ride: $h_1 = \text{_____} \text{ m}$
 - 7 Add this product to the height of the string hole: $+ h_2 = \text{_____} \text{ m}$

- This number is the height of the ride. $h_T = \text{_____} \text{ m}$

Other: There are other ways to measure distance. If you can think of one, use it. For example, a similar but more complex triangulation could be used. If you can't measure the distance L because you can't get close to the base of the structure, use the Law of Sines as in *figure c* below.



Knowing θ_1 , θ_2 , and L , the height h can be calculated using the expression:

$$h = \left[\frac{\sin \theta_1 \sin \theta_2}{\sin \theta_2 - \sin \theta_1} \right] L$$

Speed

In linear motion, the average speed of an object is given by:

$$V_{\text{ave}} = \frac{\Delta d}{\Delta t} = \frac{\text{distance travelled [in m]}}{\text{time for trip [in sec.]}}$$

In circular motion, where speed of rotation is constant:

$$V_{\text{ave}} = \frac{\Delta d}{\Delta t} = \frac{2\pi r}{\Delta t} = \frac{\text{distance in circumference of a circle [in m]}}{\text{time for one revolution [in sec.]}}$$

Challenge

Both these cases involve fairly constant speed. Be careful of measuring speed when the speed is changing. If you want to determine the speed at a particular point on the track, measure the time that it takes for the length of the train to pass that particular point.

The train's speed then is given by:

$$V_{\text{ave}} = \frac{\Delta d}{\Delta t} = \frac{\text{length of train [in m]}}{\text{time to pass point [in sec.]}}$$

In a situation where it can be assumed that total mechanical energy is conserved, the speed of an object can be calculated using energy considerations. Suppose the speed at point C is to be determined (see *figure d*). From the principle of conservation of total mechanical energy it follows that:

$$\begin{aligned} PE_A + KE_A &= PE_C + KE_C \\ mgh_A + \frac{1}{2}mv_A^2 &= mgh_C + \frac{1}{2}mv_C^2 \end{aligned}$$

Since mass is constant, solving for v_C :

$$v_C = \sqrt{2g(h_A - h_C) + v_A^2}$$

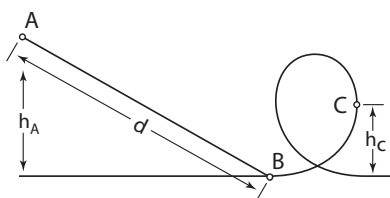
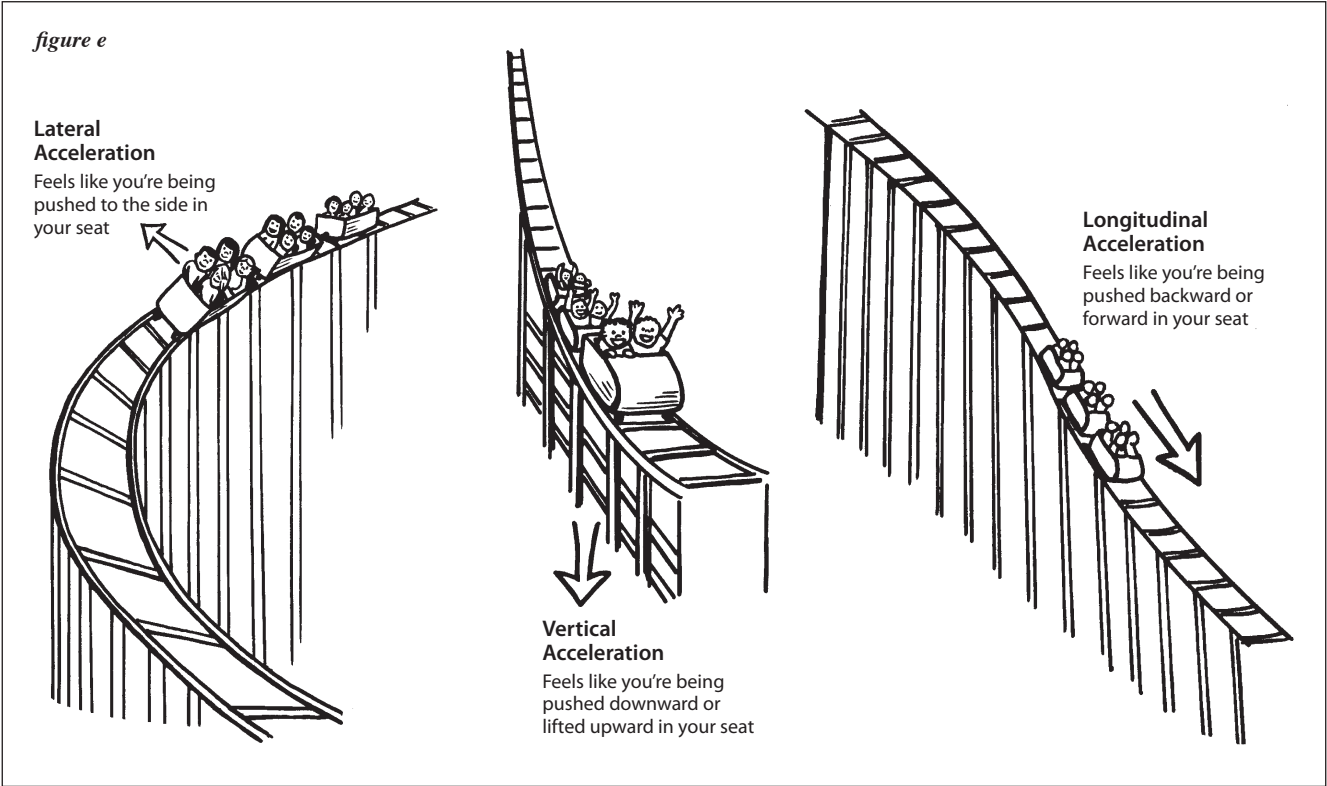


figure d

Thus by measuring the speed of the train at point A, and the height h_A and h_C , the speed of the train at point C can be calculated.

Acceleration

Accelerometers are designed to record the g forces felt by a passenger. Accelerometers are usually oriented to provide force data perpendicular to the track, longitudinally along the track, or laterally to the right or left of the track (see *figure e*).



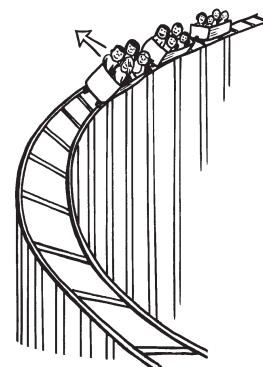
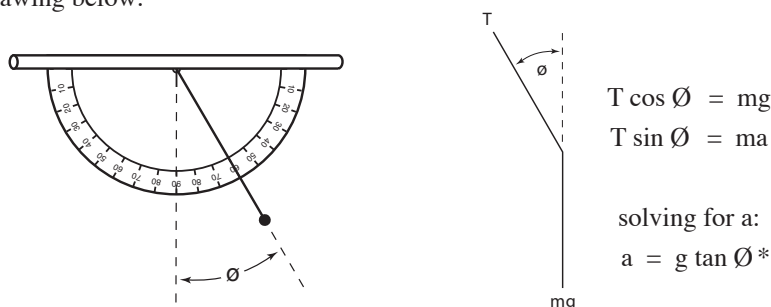
Accelerometers are calibrated in g's. A reading of 1 g equals an acceleration of 9.8 m/s². As you live on earth, you normally experience 1 g of acceleration vertically (no g's laterally or longitudinally). Listed below are the sensations of various 'g forces'. These are rough estimates, but may be helpful in estimating accelerations on the various rides.

Accelerometer Reading	Sensation
3 g	3 times heavier than normal (maximum g's pulled by space shuttle astronauts)
2 g	twice normal weight
1 g	normal weight
0.5 g	half-normal weight
0 g	weightlessness (no force between rider and coaster)
-0.5 g	half-normal weight – but directed upward away from coaster seat (weight measured on bathroom scale mounted at rider's head!)

Lateral Acceleration

Astrolab

The astrolab discussed earlier as a triangulation instrument may also be used to measure lateral accelerations. Device is held with sighting tube horizontal, and weight swings to one side as you round a curve. By measuring angle, acceleration can be determined. See drawing below:

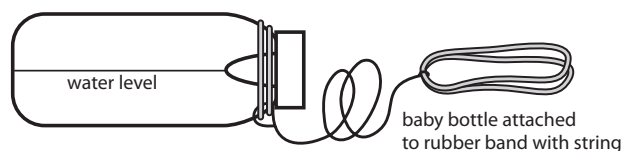


* Note: If G-meter is used, values for $a = g \tan \theta$ have been marked on the accelerometer.

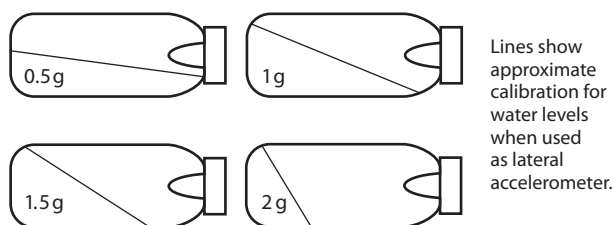
Baby Bottle

Similarly, the baby bottle accelerometer can be used to directly read an approximation of the lateral acceleration.

Lateral Accelerometer



Approximate Calibration

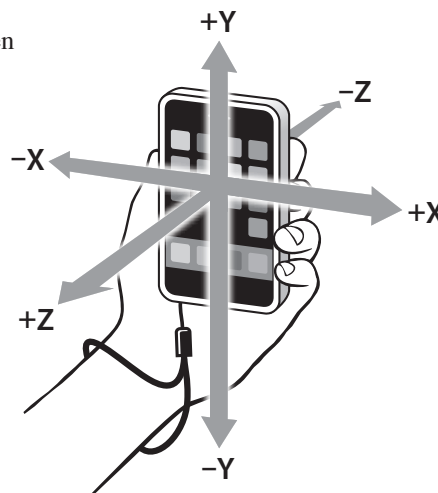


Smart Phone Accelerometers

Many smart phones have built-in accelerometers that allow them to change their screens from vertical to horizontal views. This same built-in accelerometer has been used to create a number of apps that can be loaded onto the smart phone and used to measure the acceleration of various rides at an amusement park. They range in price from free to a couple of dollars.

Once you have located an appropriate app on the smart phone (Try "accelerometer" or "roller coaster" in the app search), they are easy to use. When you get on the ride, start the app and put the smart phone in a safe place, like in a secure pocket. Once the ride is over, remove the smart phone and turn the app off. For many roller coaster accelerometer apps, you should be able to read the collected data off the screen or download the data onto a computer.

Caution: Some accelerometer apps will only give real time data you read while the ride is in operation. If you are going to collect data while holding your smart phone on the ride, secure it to your body with a tether (thin cord) in case you drop it during the ride. Using your smart phone on a field trip is your responsibility and neither the amusement park nor your school is responsible for loss or damage.



Centripetal Acceleration

With uniform circular motion remember that: $v = \frac{2\pi r}{t}$

and the centripetal acceleration is given by: $a_c = \frac{v^2}{r} = \frac{4\pi^2 r}{t^2}$

where r is the radius of the circle and t is the period of rotation.

Thus centripetal acceleration can be measured on a ride.

Vertical Acceleration

A simple device for measuring vertical accelerations is a 0-5 Newton spring scale with a 100 g mass attached. The plastic tubes with elastics and fishing weights approximate this equipment. The forces on the mass are as drawn where F_T is the reading on the scale.

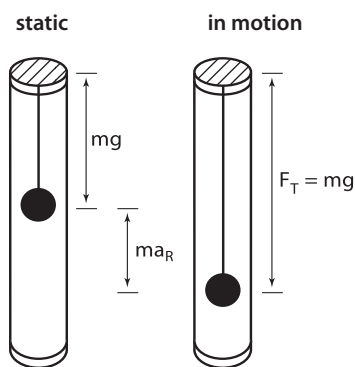
The forces on the masses are shown in the diagram.

If the person is holding the scale right side up, then:

$$F_T = mg + ma_{(\text{Ride})} \quad \text{or} \quad ma_{(\text{Total})} = mg + ma_{(\text{Ride})}$$

since m is constant,

$$a_T = g + a_R \quad \text{or} \quad a_R = a_T - g$$



If the person is holding the scale upside down against gravity as might be found at the top of the Enterprise, then:

$$a_R = -(a_T + g) \quad \text{ie. acceleration is upwards}$$

In either situation, then, the acceleration can be calculated by knowing F_T (or a_T).

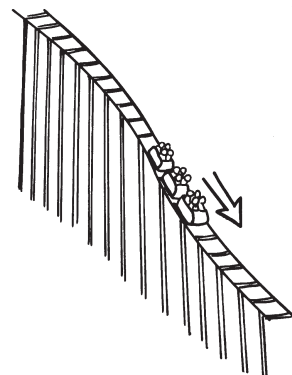
Longitudinal Acceleration

Acceleration of a person on a ride can also be determined by direct calculation.

Down an incline, the average acceleration of an object is defined as:

$$a_{\text{ave}} = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\text{change in speed}}{\text{change in time}}$$

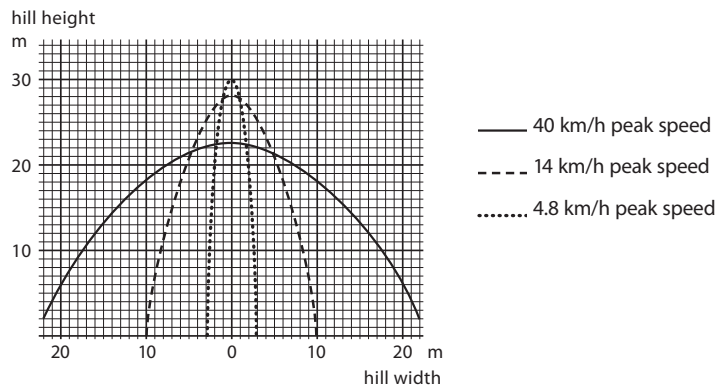
Using methods previously discussed it is possible to estimate speeds at both the top and bottom of the hill and the time it takes for the coaster to make the trip. Thus, average acceleration can be found during that portion of the ride.



Parabolic Paths

A roller coaster has a shape called a *parabola*.

The curves on the graph show three different parabolic coaster hills for three different hilltop speeds:



Describe a relationship between the sharpness or smoothness of coaster hills and their speeds.

Can you explain why coasters are built in this manner?

Roller Coaster Hill Shapes for Different Speeds at the Park

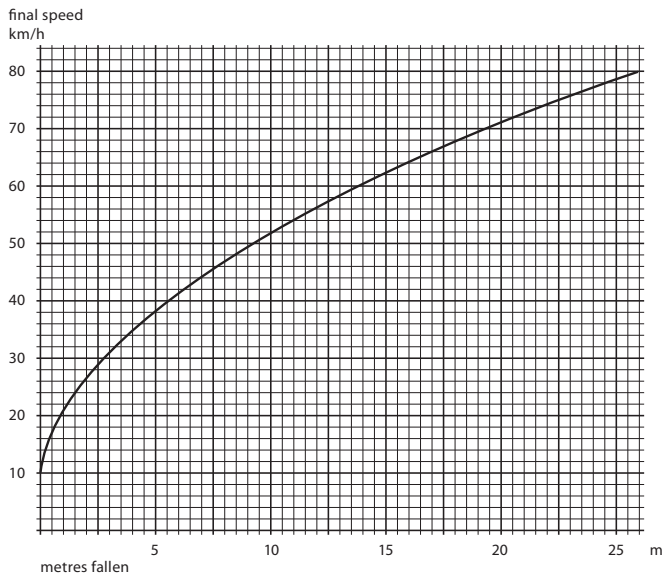
Use this graph to predict hilltop speeds for as many hilltops as you can identify on Corkscrew or the Roller Coaster. Use the space provided to try to identify the location of the hilltop in question (e.g. right before corkscrew loops; first hill; etc. – the two examples are hypothetical, and may not correspond to actual hilltops).

Ride	Speed (fast or slow)	Location of Hilltop

Speed of a Falling Roller Coaster
(assumes a free fall parabolic arc)

The graph shows the coaster’s speed as a function of falling distance. The graph assumes no speed at the hilltop, and no energy losses to friction and air resistance. This will help you estimate the speed on various hills.

As the coaster falls and its speed increases, gravitational potential energy is converted to kinetic energy.



What is the speed after falling:

5 m _____ 10 m _____ 20 m _____

How far does the coaster have to fall to be travelling:

20 km/h _____ 40 km/h _____ 60 km/h _____

In a roller coaster, part of the gravitational potential energy is converted into the heat of friction and the kinetic energy of moving air particles pushed by the moving coaster. Since this is the case, are actual coaster speeds greater or less than those shown on the graph?

What does the shape of this graph tell you about the relationship between the variables graphed (speed vs meters fallen). Explain why the shape of the graph makes sense.

Physiology of Amusement Park Rides

For each of the rides listed below, measure your pulse rate and breathing rate before and after the ride. Indicate any symptoms that you had by placing numbers of those appropriate from the list below.



Symptoms:

- | | | |
|-------------------|------------------------|-------------------------|
| 1. dry mouth | 5. cold hands/feet | 9. upset stomach |
| 2. dizziness | 6. enlarged eye pupils | 10. fast breathing |
| 3. tense muscles | 7. trembling | 11. stomach butterflies |
| 4. unable to move | 8. sweaty hands | 12. other: _____ |

Ride	Pulse Rate		Breathing Rate		Symptoms	
	<i>before</i>	<i>after</i>	<i>before</i>	<i>after</i>	<i>before</i>	<i>after</i>
Roller Coaster						
Enterprise						
Wave Swinger						
Atmosfear						
Scrambler						
Corkscrew						
Pirate						
Wild Mouse						
Scooters						
Music Express						
Hellevator						
Hell's Gate						
Crazy Beach Party						
Waterfall						
Gladiator						
Break Dance						

Ride Design

- 1** Amusement Park rides are designed to give the illusion of danger and speed. Which rides, based on the symptoms that you had, seem to give the greatest illusion?

- 2** Based on your observations, how could an amusement park design a ride to give a greater illusion of speed and danger? Diagram your design below.

Useful Formulae

$$F = ma$$

$$E_p = mgh$$

$$E_K = \frac{1}{2} mv^2$$

$$mgh = \frac{1}{2} mv^2$$

$$v^2 = 2 gh$$

$$v = \sqrt{2 gh}$$

$$g = 9.8 \text{ m/s}^2$$

$$p = m \cdot v$$

$$W = F \cdot d$$

$$P = \frac{W}{t}$$

$$d = \left(\frac{v_i + v_f}{2} \right) t$$

$$d = v_i t + \frac{1}{2} at^2$$

$$v_f = v_i + at$$

$$v_f^2 = v_i^2 + 2ad$$

$$a = \frac{v^2}{r}$$

$$F = \frac{mv^2}{r}$$

$$a = \frac{4\pi^2 r}{t^2}$$

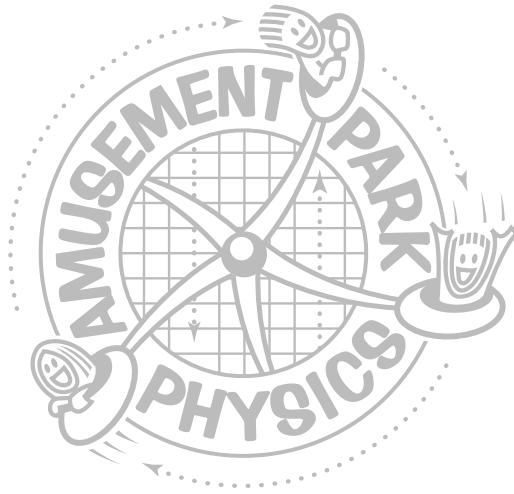
$$F = \frac{m4\pi^2 r}{t^2}$$

$$t_f = \frac{t_i}{\sqrt{1 - v^2/c^2}}$$

$$m_f = \frac{m_i}{\sqrt{1 - v^2/c^2}}$$

$$l_f = l_i \times \sqrt{1 - v^2/c^2}$$

$$c = 3.00 \times 10^8 \text{ m/s}$$



Section B

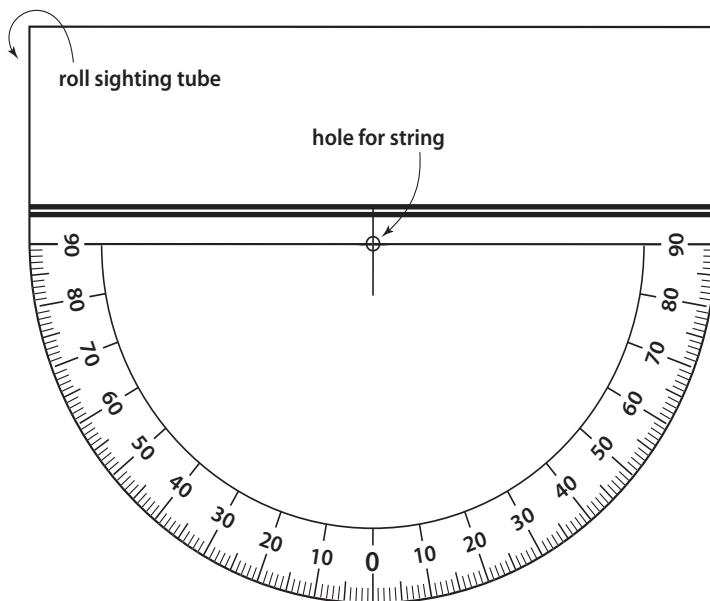
Constructing The Equipment

page	B-1	Astrolab
page	B-3	Lateral Accelerometer
page	B-3	Vertical Accelerometer
page	B-4	G-Meter

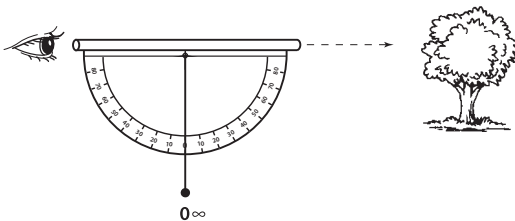
ASTROLAB

Triangulation Instrument and Accelerometer

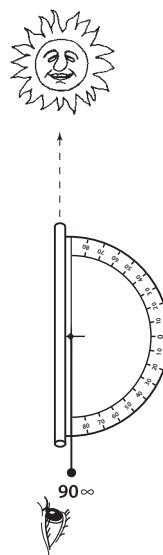
1. Cut out the Astrolab.
2. Fold the top section over a pencil and roll it down to the heavy double line to make a sighting tube.
3. Tape the rolled paper tube closed and then let the pencil slide out.
4. Glue the Astrolab to a 8" x 5" index card and trim.
5. Take about 20 cm of heavy thread and tie one end to a weight such as a key or washer. Tie the other end through the hole at the top of the Astrolab.
6. Let the thread hang free. The angle it marks off is the angular height of an object seen through the tube.



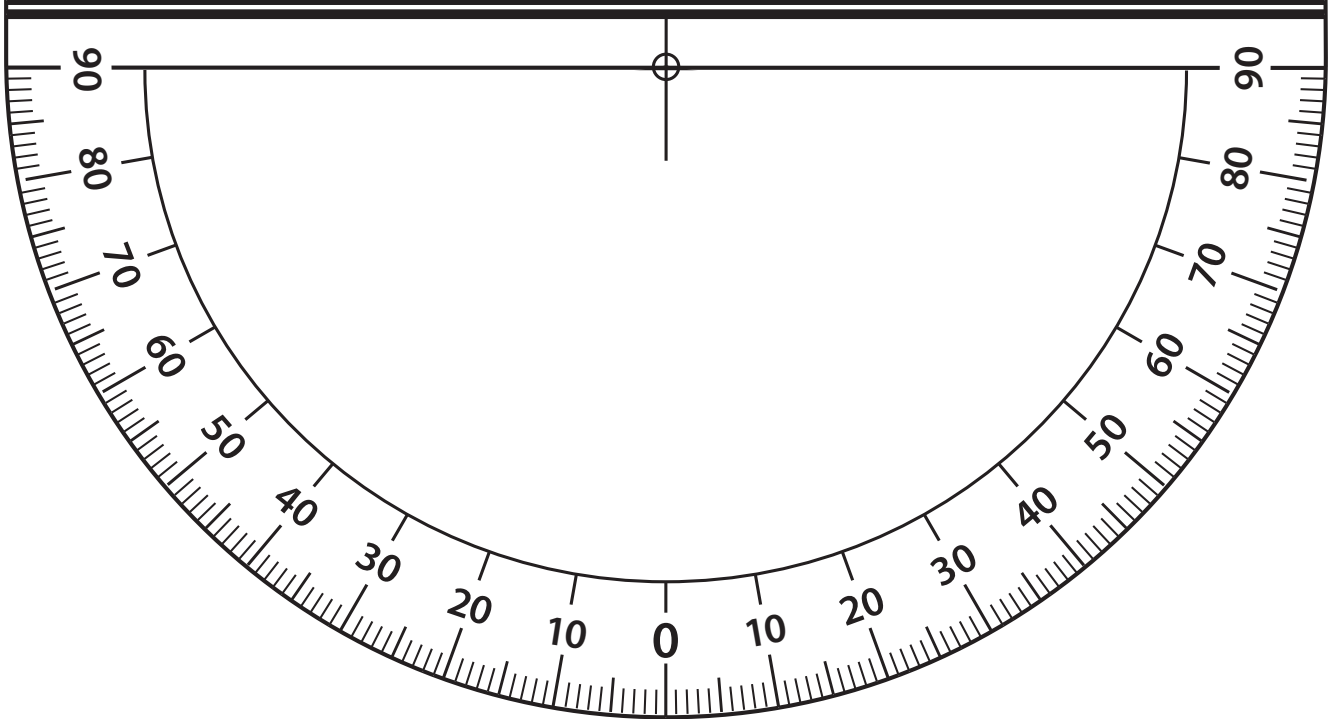
For instance:



An object on the horizon has an angular height of 0 degrees.

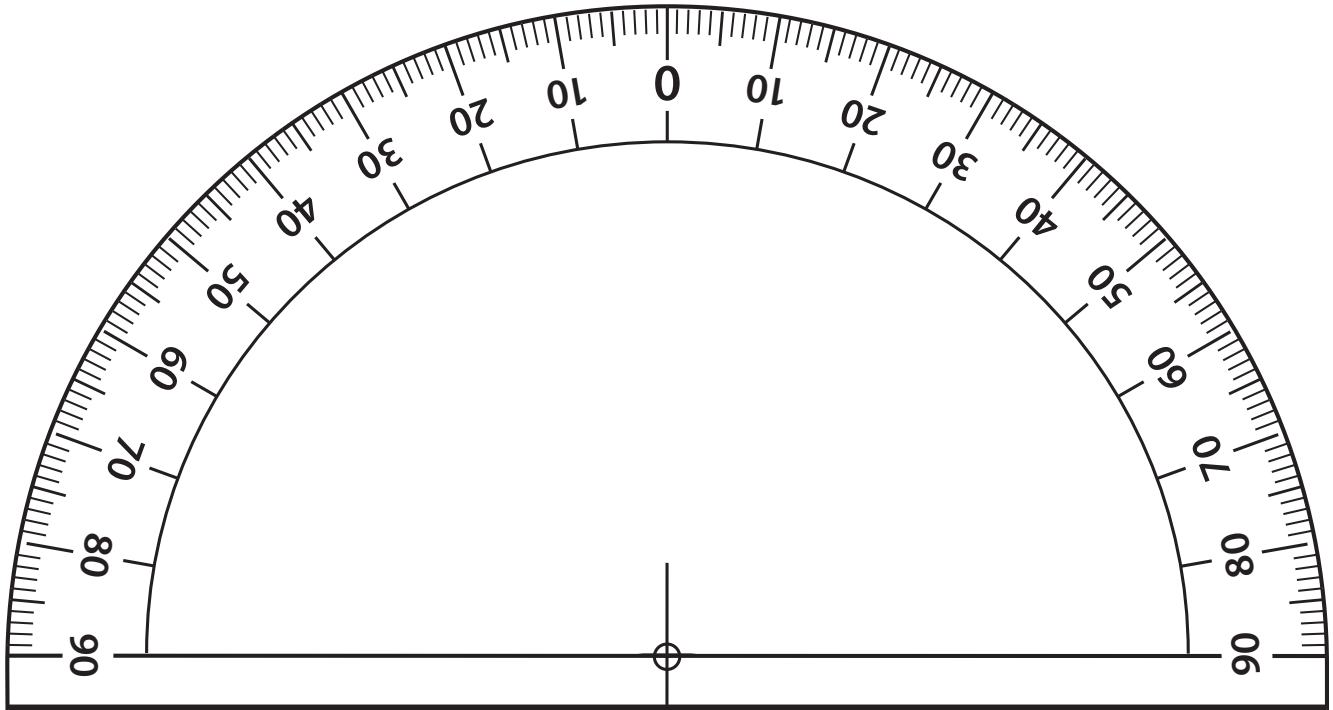


An object directly overhead has an angular height of 90 degrees.



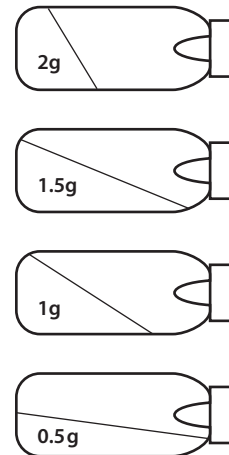
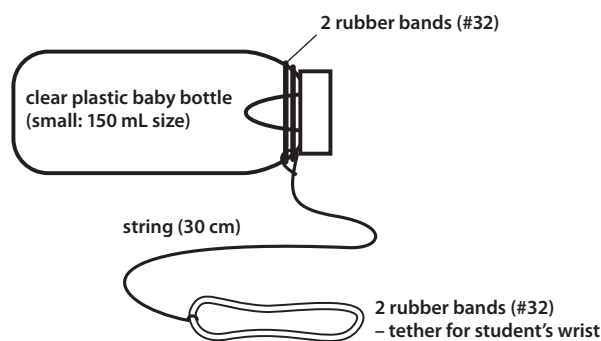
Amusement Park Physics

Section B • Constructing the Equipment



LATERAL ACCELEROMETER

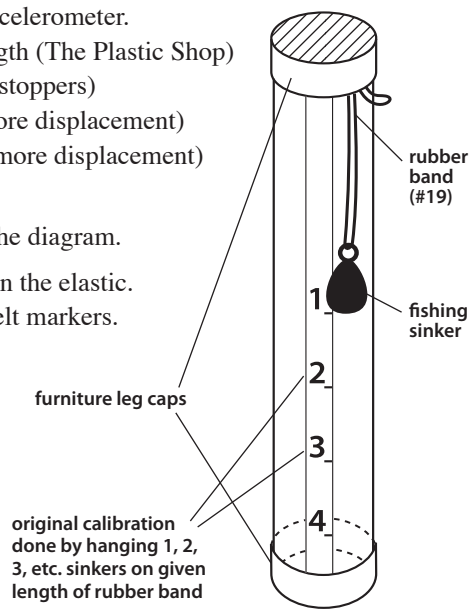
- Obtain the following (eg) materials for each accelerometer:
 - ☐ 1 small clear plastic baby bottle 150 mL (plastic only for safety reasons)
 - ☐ 4 rubber bands #32
 - ☐ 30 cm string
 - ☐ 50 mL water
 - ☐ food colouring
 - ☐ permanent felt marker
- Assemble the accelerometer as shown in the diagram.
Notice that the nipple is inverted.
- Add the coloured water to the baby bottle.



Lines show approximate calibration for water levels when used as lateral accelerometer.

VERTICAL ACCELEROMETER

- Obtain the following materials for each accelerometer.
 - ☐ 3/4" i.d. rigid plastic tubing, 20 cm length (The Plastic Shop)
 - ☐ 2 caps to fit (furniture leg caps, rubber stoppers)
 - ☐ #19 elastic band (thinner band gives more displacement)
 - ☐ 4 oz. fishing sinker (larger mass gives more displacement)
 - ☐ permanent felt marker
- Assemble the accelerometer as shown in the diagram.
- Calibrate by hanging 1, 2, 3 etc. weights on the elastic. Mark calibration on tube using indelible felt markers.



G-METER

A common unit to describe forces we feel is the “g.” One g is equal to the force of earth’s gravity. When the space shuttle takes off, astronauts feel about three g’s of force (three times the force of earth’s gravity). How many g’s do you feel on the swings, on your bicycle, on an amusement park ride, or in a car? You can make a “g” meter to measure these forces.

1. Obtain the following materials for each g meter:

- ☐ copy of g meter on next page
- ☐ thin cardboard
- ☐ glue
- ☐ scissors
- ☐ string or heavy thread
- ☐ metal washer

2. Make a copy of the g meter.

Cut out the g meter.

Glue the g meter to a thin cardboard and trim to size.

Take about 15 cm (6 inches) of heavy thread and tie one end to a weight such as a key or washer. Tie the other end through the hole at the top of the g meter.

Hold the g meter in front of you. Let the thread hang down so that it lines up with the 0 g mark.

If the g meter moves in the direction of the arrows, the weight and string will tell you the force in g’s.

In order to have the g meter work properly, the top edge must be horizontal, level with the horizon.

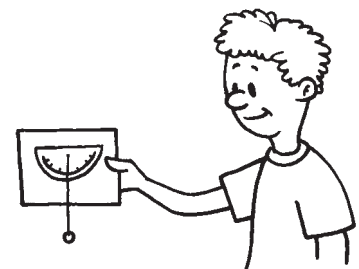
3. Now that you have your g meter, try it out.

Hold the g meter in front of you when your parents drive the car around a corner. How many g’s did you feel? Is there a difference between going around a corner slowly and going around it fast?

Hold the g meter beside you while you are on a swing. Hold it so that the arrows point in the direction you will be going. As you swing, how many g’s did you feel?

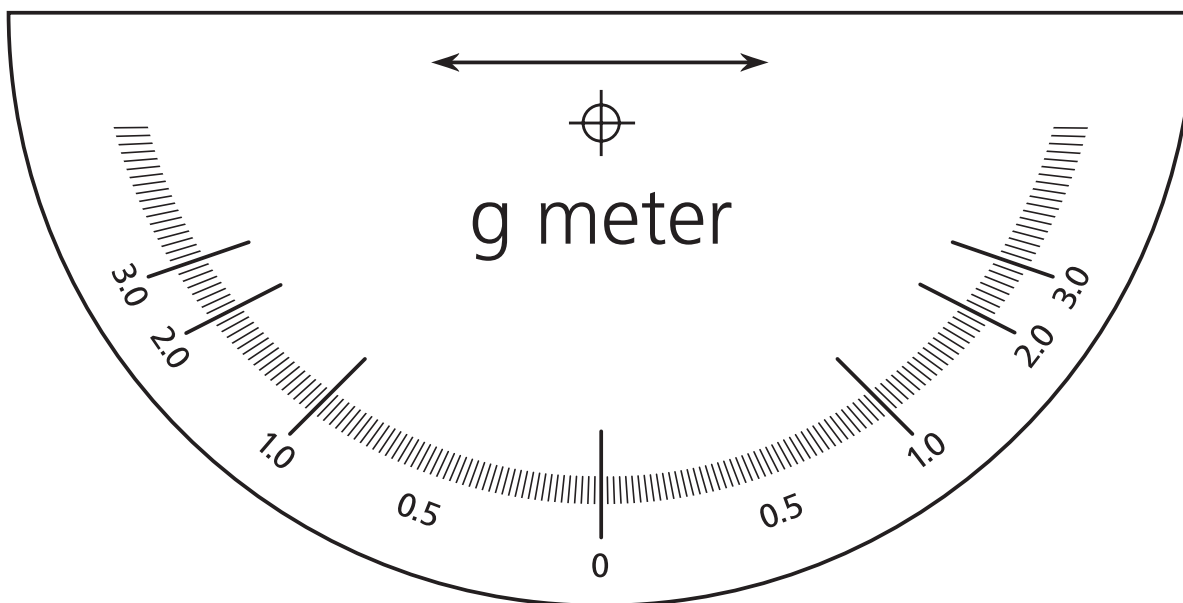
Use the g meter on the merry-go-round at the playground. Sit on the outside edge of the ride and point the arrow toward the centre. How many g’s do you feel? What happens to the number of g’s as the ride moves faster? What happens to the g’s if you sit closer to the centre of the ride?

Use the g meter on the Amusement Park rides. How many g’s does each ride create? How does each ride do it? Do some use speed or turns to create large forces?

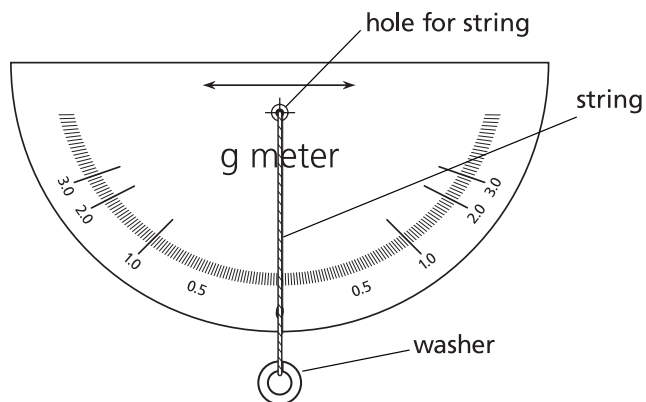


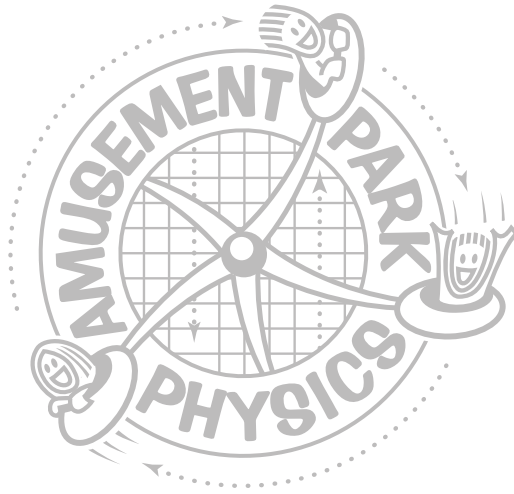
G-METER

Trace and cut out this g meter.



Attach string and washer as shown.





Section C

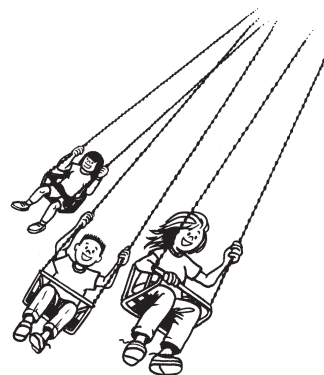
Physics II Worksheets

page C-1	Wave Swinger
page C-3	Atmosfear
page C-5	Roller Coaster
page C-7	Pirate
page C-9	Music Express
page C-11	Scooters
page C-13	Corkscrew
page C-15	Hellevator
page C-17	Hell's Gate
page C-19	Waterfall
page C-21	Crazy Beach Party
page C-23	Gladiator
page C-25	Physics 11 Quiz

Wave Swinger

A. Data

- 1 Distance from center of rotation to chain attachment _____ m
- 2 Length of chain _____ m
- 3 Radius of rotation _____ m
- 4 Time for one revolution _____ s
- 5 Angle of swing to rotation axis _____ °
- 6 Accelerometer reading _____ g's



B. Qualitative Tasks

- 1 Will an empty swing or one with someone in it ride higher? Why?

- 2 Describe your sensations as the ride increased in speed.

- 3 Explain your sensations described in #2 in terms of the physics of the ride.

- 4 Watch the ride from the beginning until it reaches full speed. What happens to the angle of the chain attached to the seats as the ride increases in speed? Why?

calculations

C. Quantitative Calculations

- ❶ Using the radius of rotation, determine the speed and centripetal acceleration of the ride. Determine the centripetal force.

_____ m/s

_____ m/s²

- ❷ Draw a vector diagram of the forces acting on you during the ride. These are due to the different accelerations you are undergoing.

- ❸ Using the calculation in #1 and the acceleration due to gravity (9.8 m/s²), determine the resultant acceleration that you should feel. How many g's was it?

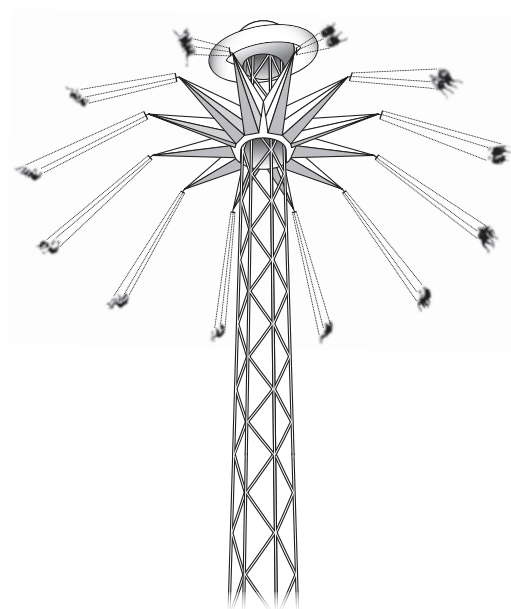
- ❹ Compare #3 with your accelerometer reading. How do they compare? Explain any differences.

- ❺ From #3 above, determine the angle at which you should have been swinging. Compare this to Data #5. Explain any differences.

Atmosfear

A. Data

- 1 Distance from center of rotation to chain attachment _____ m
- 2 Length of chain _____ m
- 3 Radius of rotation _____ m
- 4 Time for one revolution _____ s
- 5 Angle of swing to rotation axis _____ °
- 6 Accelerometer reading _____ g's



B. Qualitative Tasks

- 1 Will an empty swing or one with someone in it ride higher? Why?

- 2 Describe your sensations as the ride increased in speed.

- 3 Explain your sensations described in #2 in terms of the physics of the ride.

- 4 Watch the ride from the beginning until it reaches full speed. What happens to the angle of the chain attached to the seats as the ride increases in speed? Why?

calculations

C. Quantitative Calculations

- ➊ Using the radius of rotation, determine the speed and centripetal acceleration of the ride. Determine the centripetal force.

_____ m/s

_____ m/s²

- ➋ Draw a vector diagram of the forces acting on you during the ride. The forces are due to the different accelerations you are undergoing. Use the angle of the swing to make your vector diagram as accurate as possible.

- ➌ Using the calculations in #1, the vector diagram in #2 and the acceleration due to gravity (9.8 m/s), determine the resultant acceleration that you should feel. How many g's was it?

- ➍ Compare the value in #3 to your accelerometer reading. Explain any similarities or differences. What is your percent error?

- ➎ From #3 above, determine the angle at which you should have been swinging. Compare this to Data #5. Explain any differences.

Roller Coaster

A. Data

Length of track 1,001 m

Measurements while standing in line:

Time for ride: _____ s

Length of train: _____ m

(*hint: length of car \times number of cars*)

Measurements while on ride: (using accelerometer)

(*Hint: Sit in rear cars to make measurements on ride*)

Maximum **g** _____ g's at _____ (location)

Minimum **g** _____ g's at _____ (location)

Measurements from observation area:

1. Distance from hill to observation area: _____ m

Angle: _____ °

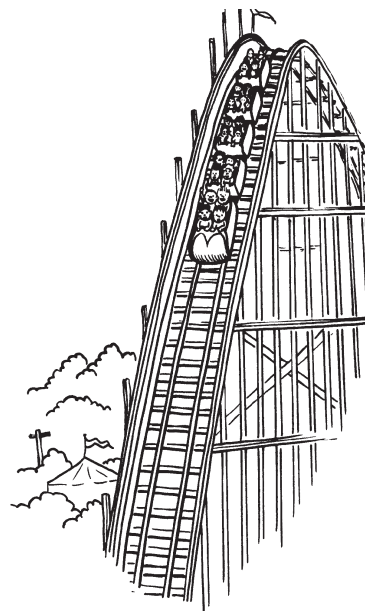
Calculated height of hill: _____ m

2. Time for train to go from bottom to top of first hill _____ s

3. Time for train to pass point at top of hill _____ s

4. Time for train to pass point at bottom of hill _____ s

5. Time for train to go from top of hill to bottom _____ s



B. Qualitative Observations

1 Where was the highest hill on the ride? Why is it there?

2 Did you feel lateral forces while on the ride (i.e. were you thrown from side to side in the train car)? If so, what forces caused that feeling? Use a diagram if necessary to help explain.

3 Where on the ride did you feel you were going the fastest? Why?

- 4** Where on the ride did you feel like you were lifted off your seat? How did the ride cause that feeling?

- 5** Draw a free body diagram labeling the forces acting on you at the bottom of the first hill.
Is the net force greater or less than normal?

calculations

C. Quantitative Calculations

- 1** Average speed of train for total ride (show work):

_____ m/s
_____ km/h

- 2** Speed at top of first hill (show work):

_____ m/s
_____ km/h

- 3** Speed at bottom of first hill (show work):

_____ m/s
_____ km/h

- 4** Calculate the acceleration of the train during the trip down the first hill.

_____ m/s²

- 5** If each car has a mass of 1200 kg, and assuming the coaster is filled with riders whose average mass is the same as yours, how much total work is done getting the filled coaster to the top of the first hill?

_____ joules

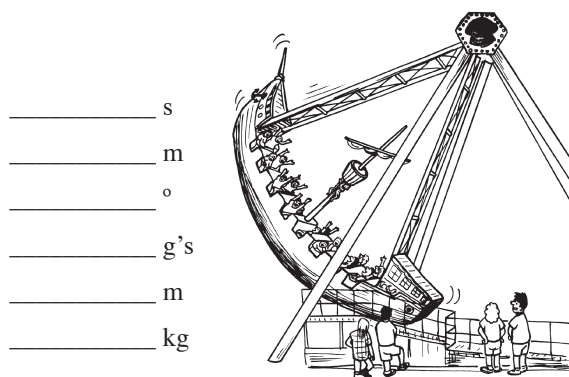
- 6** How much power does the motor have to put out in order to lift the loaded coaster to the top of the first hill? (Answer in both watts and horsepower: 746 watts = 1 hp)

_____ watts
_____ hp

Pirate

A. Data

- ➊ Time for one period (complete cycle)
- ➋ Estimated radius of the ship's path
- ➌ Maximum angle of displacement
- ➍ Maximum accelerometer reading
- ➎ Maximum height reached by the car
- ➏ Approximate mass of car and riders



B. Qualitative Tasks

- ➊ Consider the rocking boat described above as a pendulum. In a simple pendulum, the mass is considered to be concentrated at the end of a weightless string.

A simple pendulum at small displacements exhibits simple harmonic motion with the period t of the pendulum's swing expressed by the following relationship:

$$t = 2\pi \sqrt{\frac{L}{|g|}} \quad \text{Where } L = \text{the length of the pendulum's string.}$$

Calculate the period of the Pirate if it were a pendulum.

_____ s

- ➋ From your results above, decide if the boat is a simple pendulum. Why or why not?

- ➌ In each arc, where did you feel:

a) the strongest push against your back?

b) the most pressure against your seat?

c) the least pressure against your seat?

- ➍ When did you feel you were going the fastest?

- 5** If you have a vertical accelerometer, hold it in front of you during the ride. Observe the motion of the suspended mass.
- a) In what part of the ride was the mass pulled farthest down the tube?

- b) In general, describe the motion of the suspended mass during an arc and during a loop.

calculations

C. Quantitative Calculations

- 1** Calculate the distance of the ship's arc.

_____m

- 2** Calculate the ship's average speed in the arc.

a) _____m/s

b) _____km/h

- 3** Calculate the potential energy of the ride at its highest point.

- 4** Use the Law of Conservation of Energy ($E_{\text{initial}} = E_{\text{final}}$) to determine the velocity of the ride at its lowest point. Compare that value to what you calculated in question 2 and explain any differences.

Music Express

A. Data

- ➊ Radius of the ride
- ➋ Time for one revolution
- ➌ Height gain to the highest point of the ride

_____ m

_____ s

_____ m



B. Qualitative Tasks

- ➊ Describe the sensations that you felt on the ride. Include any differences you felt as the ride progressed.

- ➋ Was there any difference in the sensation of speed at the highest point of the ride compared to the lowest point? If so, explain.

- ➌ Imagine that all the music system speakers were placed at one spot next to the ride. Would the music sound any differently to the passengers? Explain.

calculations

C. Quantitative Calculations

- ❶ What is the distance a car travels in one revolution?

_____ m

- ❷ What is the average speed that the cars go during the ride?

_____ m/s

- ❸ If each car has a mass of 200 kg, what is the increase in potential energy as the car moves from the lowest point to the highest point on the ride?

_____ joules

- ❹ What happens to that energy that the cars gained in going to the highest point in the ride?

- ❺ Use the time dilation equation to calculate the difference in time for a clock on the ride and one not on the ride due to the relativistic effect caused by velocity. Is this time difference significant?

Note: Many of the **Roller Coaster** questions can apply to this ride also!

Scooters

A. Qualitative Tasks

Make observations that will allow you to answer the following questions.

State the observed facts that justify each of your answers.



- 1 If your car is hit head on by another car, what direction is your car accelerated? How do you know?

- 2 If your car is hit head on by another car, what determines whether your car continues to move forward or backward after the collision?

- 3 If you hit another car on the side, at right angles to its direction of forward motion, what immediately happens to the motion of the other car upon impact? Of course, the other driver may immediately respond by changing the speed and direction of his/her car. This is a difficult observation to make unless you work with a friend in the other car.

- 4 What is the role of friction between the cars and the floor? In which direction do you think that the friction is greater?

- 5 Answer these questions using the concepts of energy, impulse and Newton's Laws of Motion. Don't use vague terms like "shock".

a) What is the reason for having the rubber bumpers around the cars?

b) Why would you not design a bumper car with very soft bumpers?

c) Why would you not design a bumper car with no bumpers at all?

- 6** If you were riding the only car with a much smaller mass than the other cars, how would your ride be different from the one you have just experienced? Explain why.

- 7** Under what conditions do the following happen?

a) driver will feel the strongest jolt.

b) driver will be thrown forward.

c) car will accelerate at the crash.

d) driver will be thrown backward.

e) car will change direction at crash.

- 8** How is electrical energy supplied to the Bumper Cars? Describe and draw a complete circuit for one of the cars.

- 9** During a collision, is kinetic energy conserved? Explain.

Corkscrew

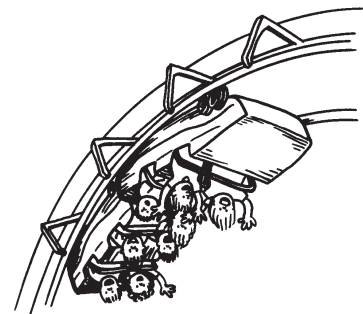
Note: Many of the **Roller Coaster** questions can apply to this ride also!

A. Data

Length of track 702m

Measurements while standing in line:

- | | |
|--------------------------------------|---------|
| (a) height of first hill | _____ m |
| (b) Approximate length of first drop | _____ m |
| (c) time for first drop | _____ s |
| (d) time for entire ride | _____ s |



Measurements while on ride: (using accelerometer)

Maximum **g** _____ g's at _____ (location)

Minimum **g** _____ g's at _____ (location)

Measurements from observation area: (Collect data you need to answer the questions)

- | | |
|--|---------|
| 1. Height of first hill: | _____ m |
| 2. Time for train to go from bottom to top of first hill | _____ s |
| 3. Time for train to pass point at top of hill | _____ s |
| 4. Time for train to pass point at bottom of hill | _____ s |
| 5. Time for train to go from top of hill to bottom | _____ s |

B. Qualitative Tasks

- ① Where is the highest point of the ride? Why is it there?

- ② Where on the ride did you feel you were going the fastest? How fast (in m/s)?

- ③ Where on the ride did you feel like you were lifted off your seat? How did the ride cause that feeling?

- ④ How accurate were your accelerometer measurements? Explain.

- ⑤ Does the ride always rotate in the same direction? Explain.

calculations

C. Quantitative Calculations

Average speed of train for total ride (show work):

_____ m/s
 _____ km/h

2 Speed at top of first hill (show work):

_____ m/s
 _____ km/h

3 Speed at bottom of first hill (show work):

_____ m/s
 _____ km/h

4 Calculate the acceleration of the train going down the hill.

_____ m/s²

5 If each car has a mass of 1350 kg, and assuming the coaster is filled with riders whose average mass is the same as yours, how much total work is done getting the filled coaster to the top of the first hill?

_____ joules

6 How much power does the motor have to put out in order to lift the loaded coaster to the top of the first hill? (Answer in both watts and horsepower: 746 watts = 1 hp)

_____ watts
 _____ hp

7 Although question #1 asks for the average speed for the total ride, ride the train again and calculate the average speed of the ride beginning with the drop on the first hill and ending just before braking begins at the end. You'll need to measure the time for that part of the trip and subtract the amount of track that is not included in this measurement.

_____ m/s
 _____ km/h

Hellevator

A. Data

- 1 Height of tower _____ m
- 2 Height of riders at top of flight _____ m
- 3 Mass of riders (estimated) _____ kg
- 4 Time of ride up _____ s
- 5 Time of ride down (freefall) _____ s
- 6 Measure the forces:
 - during ride up _____ g
 - at top of ride _____ g
 - during ride down _____ g
 - at bottom of ride _____ g

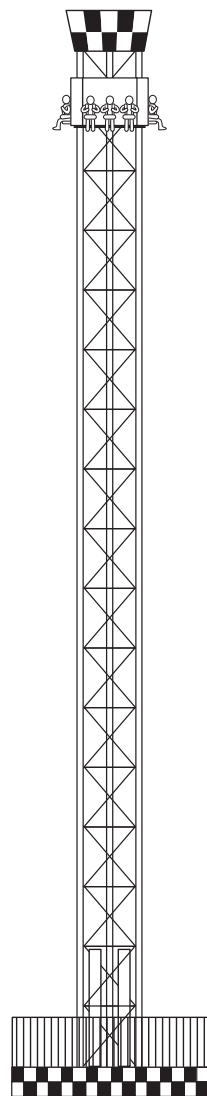
B. Qualitative Tasks

- 1 Have the riders take their pulse rate:
 - (a) before they get on this ride. _____
 - (b) immediately after they have finished this ride. _____
 - (c) Explain any changes. _____

- 2 In a few words, have the riders describe how they felt:
 - (a) before the ride started _____
 - (b) at the highest point of the ride _____
 - (c) during free fall _____
 - (d) at the end of the ride _____

- 3 Where on the ride do riders experience:
 - (a) more gs than normal _____
 - (b) less gs than normal _____

- 4 Explain the riders' sensations and the gs they felt in #3 in terms of the physics of the ride.



calculations

C. Quantitative Tasks

- 1** Calculate the average velocity as the riders travel up the ride in m/s.

_____ m/s

- 2** Calculate the final velocity the riders reach at the end of their free fall in m/s.

_____ m/s

- 3** Use the maximum height the cars reach to calculate the initial velocity of the ride.

_____ m/s

- 4** If the acceleration up the tower happens during the first 5 meters, what is the acceleration during this time?

_____ m/s^2

_____ g's

- 5** Use the acceleration found in #4 above to calculate the force necessary to achieve the acceleration.

_____ N

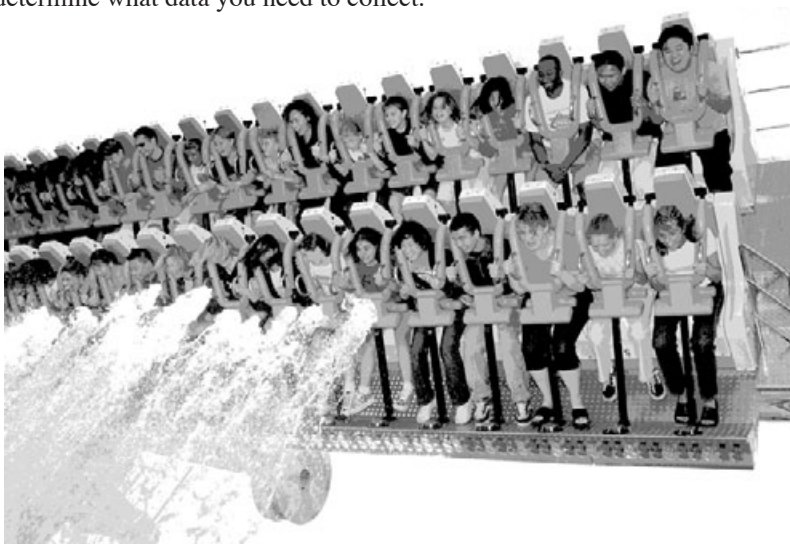
- 6** What is the acceleration during the free fall part of the ride?

_____ m/s^2

Hell's Gate

Stand in a position where you can observe the ride. Take data and answer the following questions. After reading the questions, you must determine what data you need to collect.

A. Data



Measurements while on ride: (using accelerometer)

Maximum **g** _____ g's at _____ (location)

Minimum **g** _____ g's at _____ (location)

B. Qualitative Tasks

1 Have the riders take their pulse rate:

- (a) before they get on this ride. _____
- (b) immediately after they have finished this ride. _____

2 In a few words, have the riders describe how they felt:

- (a) before the ride started _____
- (b) during the ride _____
- (c) after the ride ended _____

3 Where on the ride do the riders experience:

- (a) more g's than normal _____
- (b) less g's than normal _____

- 4 Explain the riders' sensations and the g's they felt in #3 in terms of the physics of the ride.

calculations

C. Quantitative Tasks

- 1 Calculate the average speed during the ride in m/s.

_____ m/s

- 2 Estimate the mass of the ride and the riders.

_____ kg

- 3 Calculate the amount of work necessary to move the ride and the riders from the lowest point to the highest point on the ride.

_____ Joules

- 4 How much power do the motors have to supply to move the ride and the riders in calculation #3?

_____ kW

- 5 Present data and calculations for any other portion of the ride.

Waterfall

Stand in a position where you can see the final drop of both rides, take data and answer the following questions. Some data will be provided, some will not. After reading the questions, you must determine what data you need to collect.

A. Data



B. Qualitative Tasks

- 1 Look at the place where each boat begins its final drop. What can you say about the vertical height of each of these? Is one higher than the other, or are they both about the same height?

- 2 According to your answer to the last question and considering the data which is supplied, what can you say about the potential energy of each boat when they have people of roughly the same weight?

- 3 As you watch the boats make their drop, do you notice any difference in the path that each takes to the bottom?

- 4 When each boat gets to the bottom of the run, what has happened to the potential energy each one had at the top?

- 5 Does the amount of potential energy each loses depend on the path each one takes to the bottom? Explain why or why not.

- 6 Considering everything you've answered so far, what would you expect to be true of the final velocity of each boat? Is one higher than the other or are they the same?

- 7 If you put more people into a boat (thus increasing the mass) would you notice any difference in the final speed?

calculations

C. Quantitative Calculations

- 1** Look at the place where each boat begins its final drop. Determine the vertical distance of this drop for each boat using any method you prefer. Is one higher than the other, or are they both about the same height? Show work or describe method for credit.

- 2** Using potential and kinetic energy relationships, calculate the theoretical maximum speed at the end of the final drop for each ride (assume no energy loss). Before you complain that this is too much work, think about it: will the different path each ride takes to the bottom affect the final speed? Show work for full credit.

- 3** Go to a place where you can see the end of each ride. Calculate the final speed using the marked distances (see Data section). Should the speeds agree? Show work for full credit. Assume zero velocity at the top.

- 4** Do the results of #2 and #3 agree? List two reasons why they might not.

- 5** You have calculated the theoretical maximum speed at the bottom of the hill (#2) and you have measured the actual speed at the bottom of the hill (#3). Now select one of the hills and calculate the percent of energy that was at the top of the drop which was lost to friction during the drop. Assume the boat began from rest.

Extra for Experts: Do the same calculations as above but consider the boat's kinetic energy before making the final drop.

Crazy Beach Party

A. Data

Length of pendulum arm _____ m

Radius of seat rotation _____ m

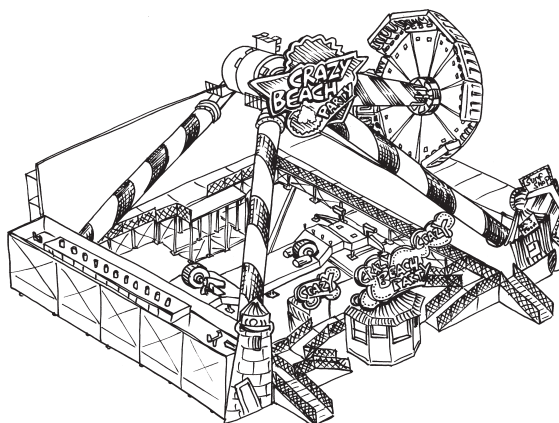
Time for one pendulum swing _____ s

Time for one seat rotation _____ s

Acceleration reading during pendulum swing _____ g's

Acceleration reading during seat rotation _____ g's

of degrees the pendulum moves through _____ °



B. Qualitative Tasks

- 1 What forces do you feel as the ride first starts to swing back and forth? Explain how the ride creates them.

- 2 What forces to you feel as the ride begins to rotate? Explain how the ride creates them.

- 3 Describe your feelings when the ride is moving its fastest with both the pendulum swing and rotation.

- 4 What happens on the ride to cause the feelings in question #3? Use physics terms to describe this.

- 5 How does your pulse rate change from the time before the ride first starts to after it reaches full speed and then ends?

calculations

C. Quantitative Tasks

- ❶ Use your data and the pendulum formula to determine if the ride acts like a true pendulum. In a simple pendulum, the mass is considered to be concentrated at the end of a weightless string.

A simple pendulum at small displacements exhibits simple harmonic motion with the period t of the pendulum's swing expressed by the following relationship:

$$t = 2\pi \sqrt{\frac{L}{g}} \quad \text{Where } L = \text{the length of the pendulum's string.}$$

Calculate the period of the ride if it were a pendulum.

_____ s

- ❷ Determine the # of °/s that the pendulum moves at maximum speed.

_____ °/s

- ❸ Describe the ride's motion relative to the following frames of reference. Use diagrams if helpful.

a. Relative to a person sitting directly across from you.

b. Relative to the centre of the ride.

c. Relative to a person standing in line.

Gladiator

This ride uses unusual centripetal force.

Procedure and Questions

Ride the Gladiator and answer the following questions.

- 1** Does the large wheel at the centre of this ride turn clockwise (move to the left) or counter-clockwise (move to the right)?



- 2** What direction(s) does the small wheel, that holds the ride cars, turn? If it turns different directions, keep track of the direction of the turns for one full ride. For example, record how many times it turns in each direction.

Spins left:

Doesn't spin:

Spins right:

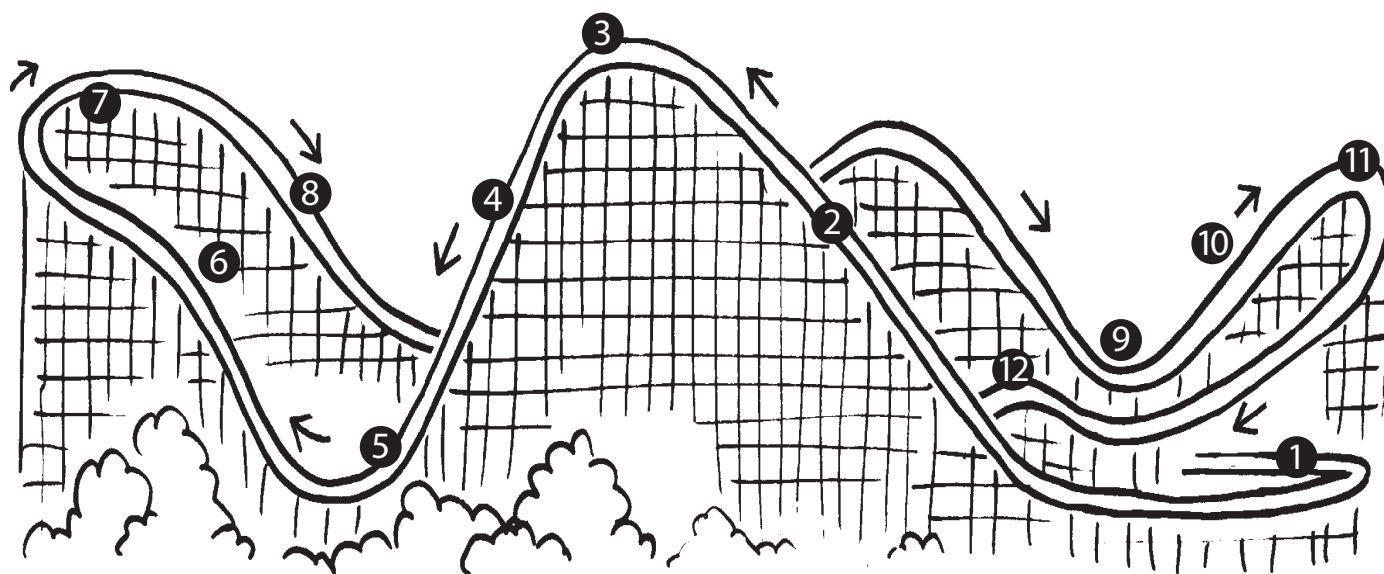
- 3** Describe the forces you felt while on the ride. Are the forces always the same or do they change during the ride? If the forces change on the ride, where do they change? Draw a free body diagram of the forces that act on you at two different times on the ride.

[illegible]

- 4 How many g's does this ride create? Are the g's constant or do they change? Explain your answer.

- 5 Concentrate your attention on one rider during the ride and follow this single rider's path for at least one full revolution of the ride. Draw a diagram of the path he took for that single revolution. (Your diagram should be what you would see if you watched the rider's path while looking down on the ride from above.)

Physics II Quiz



List the number (or numbers) on the roller coaster that best match the phrases below:

- _____ freefall area
- _____ weightless zone
- _____ where a machine makes the ride go instead of gravity
- _____ where car moves because of momentum roll
- _____ banked curve
- _____ parabolic arc
- _____ centripetal force at work
- _____ greatest gravitational potential energy
- _____ where the coaster's velocity increases
- _____ high g-force zone
- _____ where car moves the slowest assuming a frictionless track
- _____ where riders decelerate
- _____ greatest kinetic energy

On roller coasters positive g 's are felt for very short time periods. Periods of 0 to 1 g are maximized to minimize rolling friction with the track. Negative g 's are avoided as much as possible for obvious safety reasons.

Recall your own roller coaster experiences and combine them with your understanding of Physics.

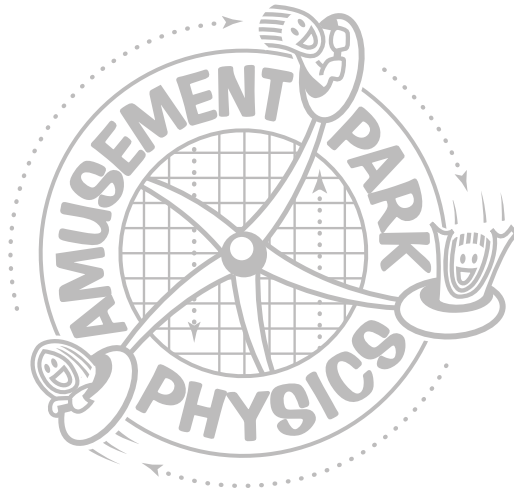
- a. When would you expect to pull the most g 's on a roller coaster?

- b. When would you expect to be nearly weightless?

- c. When would you expect to pull negative g 's? Which seat would be most likely to provide this experience?

- d. Where would you expect to pull lateral g 's (to the sides of the coaster)?

- e. Where would you expect to pull longitudinal g 's (forward or backward)?



Section D

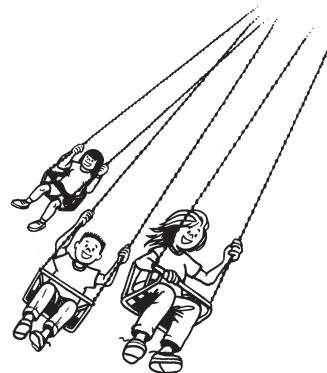
Physics 12 Worksheets

page D-1	Wave Swinger
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page D-25	Physics 12 Quiz

Wave Swinger

A. Data

- 1 Distance from center of rotation to chain attachment _____ m
- 2 Length of chain _____ m
- 3 Radius of rotation _____ m
- 4 Time for one revolution _____ s
- 5 Angle of swing to rotation axis _____ °
- 6 Accelerometer reading _____ g's



B. Qualitative Tasks

- 1 Will an empty swing or one with someone in it ride higher? Why?

- 2 Describe your sensations as the ride increased in speed.

- 3 Explain your sensations described in #2 in terms of the physics of the ride.

- 4 Watch the ride from the beginning until it reaches full speed. What happens to the angle of the chain attached to the seats as the ride increases in speed? Why?

calculations

C. Quantitative Calculations

- ➊ Using the radius of rotation, determine the centripetal acceleration of the ride. Determine the centripetal force.

_____ m/s^2

_____ N

- ➋ Draw a vector diagram of the forces acting on you during the ride. These are due to the different accelerations you are undergoing.

- ➌ Using the calculation in #1 and the acceleration due to gravity (9.8 m/s^2), determine the resultant acceleration that you should feel. How many g's was it?

_____ g's

- ➍ Compare #3 with your accelerometer reading. How do they compare? Explain any differences.

- ➎ From #3 above, determine the angle at which you should have been swinging. Compare this to Data #5. Explain any differences.

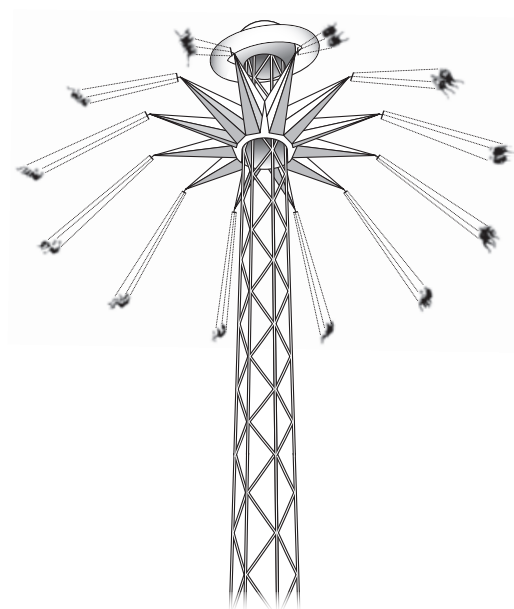
- ➏ What is the tension in the chain of the swing that held you? Assume the chain and chair have a mass of 25 kg.

_____ N

Atmosfear

A. Data

- ① Distance from center of rotation to chain attachment _____ m
- ② Length of chain _____ m
- ③ Radius of rotation _____ m
- ④ Time for one revolution _____ s
- ⑤ Angle of swing to rotation axis _____ °
- ⑥ Accelerometer reading _____ g's



B. Qualitative Tasks

- ① Will an empty swing or one with someone in it ride higher? Why?

- ② Describe your sensations as the ride increased in speed.

- ③ Explain your sensations described in #2 in terms of the physics of the ride.

- ④ Watch the ride from the beginning until it reaches full speed. What happens to the angle of the chain attached to the seats as the ride increases in speed? Why?

calculations

C. Quantitative Calculations

- ➊ Using the radius of rotation, determine the speed and centripetal acceleration of the ride. Determine the centripetal force.

_____ m/s

_____ m/s²

- ➋ Draw a vector diagram of the forces acting on you during the ride. The forces are due to the different accelerations you are undergoing. Use the angle of the swing to make your vector diagram as accurate as possible.

- ➌ Using the calculations in #1, the vector diagram in #2 and the acceleration due to gravity (9.8 m/s), determine the resultant acceleration that you should feel. How many g's was it?

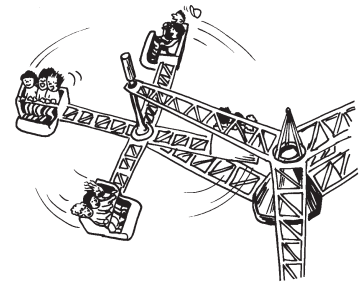
- ➍ Compare the value in #3 to your accelerometer reading. Explain any similarities or differences. What is your percent error?

- ➎ From #3 above, determine the angle at which you should have been swinging. Compare this to Data #5. Explain any differences.

Scrambler

A. Data

- 1 Estimated radius of primary axis
(center of ride to center of cluster) _____ m
- 2 Estimated radius of secondary axis
(center of cluster to rider) _____ m
- 3 Turning rate around primary axis _____ rev/min
- 4 Clockwise or counterclockwise rotation
around primary axis _____
- 5 Turning rate around secondary axis _____ rev/min
- 6 Clockwise or counterclockwise rotation
around secondary axis _____
- 7 Concentrate your attention on one rider, and follow this single rider's motion for at least one full rotation of the ride. Draw the path of the rider for one turn.
(Your sketch should be what you would see the rider do if you were looking down on the rider from above.)



B. Qualitative Tasks

- 1 Describe the sensations you felt during the ride.

- 2 Describe the direction of both the primary and secondary rotation. Are they in the same or different directions?

- 3 What effect does #2 have on your sensations during the ride?

- 4 What would happen if both the primary and secondary rotation were in the same direction?
How would a ride like that feel?

calculations

C. Quantitative Tasks

- 1 Determine the centripetal acceleration around the primary axis.

_____ m/s^2

- 2 Determine the centripetal acceleration around the secondary axis..

_____ m/s^2

- 3 Draw a diagram showing both rotation axes. Where is acceleration additive?
Where is acceleration in opposite direction?

- 4 Give the net acceleration at each point in #3.

Enterprise

A. Data

Estimated radius of the ride

_____ m

Estimated time of one revolution when ride is at full speed.

_____ s

Measured values (use accelerometer):

Acceleration experienced at side of vertical path

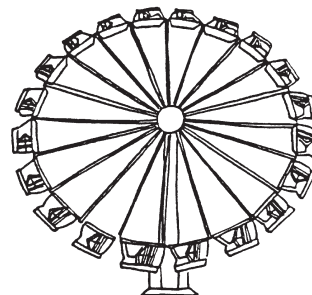
_____ g's

Acceleration experienced at top of vertical path

_____ g's

Acceleration experienced at bottom of vertical path

_____ g's



B. Qualitative Tasks

- 1 Observe the Enterprise as it is starting out. As it starts to move in a horizontal orbit, what do you notice about the cars in relationship to the ride?

- 2 Continue to watch the ride as it changes from horizontal to vertical. Now what do you notice about the cars in relationship to the ride?

- 3 Why do you suppose that the cars changed their positions?

- 4 How long does it take one car to go completely around on this ride?

- 5 While riding the ride, notice at what particular point you appear to be going faster. Where on the ride do you feel this? (At the top, bottom, etc.) Why do you suppose that this is so?

- 6 Also notice at what point in the ride you appear "heavier". Where on the ride do you feel this? Why do you suppose that this is so?

- 7** Observe the movement of the weight on your Astrolab as you experience the ride. Describe the movement of the weight through one complete turn of the ride when the ride is going sideways and when the ride is going up and down.

calculations

C. Quantitative Calculations

- 1** Calculate the circumference of the ride.

_____ m

- 2** Calculate the frequency of the ride at full speed.

_____ rev/s

- 3** Calculate the centripetal acceleration during the ride and the net force at the top and bottom of each turn.

 F_c _____ m/s^2 F_{net} at top _____ N F_{net} at bottom _____ N

- 4** Compare the values of the calculated F_{net} and those from your accelerometer. Explain any differences.

- 5** Where is acceleration at its highest value? At the top or the bottom of the ride?

- 6** Draw a free body diagram of the forces acting on you at the top and bottom of each turn. How does this help explain your calculations and accelerometer readings?

Roller Coaster

A. Data

Length of track 1,001 m

Measurements while standing in line:

Time for ride: _____ s

Length of train: _____ m

(hint: length of car \times number of cars)

Measurements while on ride: (using accelerometer)

(Hint: Sit in rear cars to make measurements on ride)

Maximum **g** _____ g's at _____ (location)

Minimum **g** _____ g's at _____ (location)

Measurements from observation area:

1. Distance from hill to observation area: _____ m

Angle: _____ °

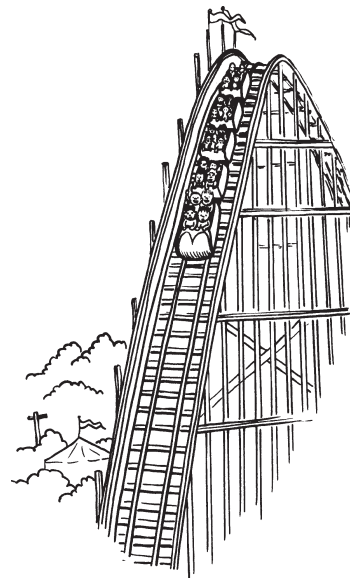
Calculated height of hill: _____ m

2. Time for train to go from bottom to top of first hill _____ s

3. Time for train to pass point at top of hill _____ s

4. Time for train to pass point at bottom of hill _____ s

5. Time for train to go from top of hill to bottom _____ s



B. Qualitative Observations

1 Where was the highest hill on the ride? Why is it there?

2 Did you feel lateral forces while on the ride (i.e. were you thrown from side to side in the train car)? If so, what forces caused that feeling? Use a diagram if necessary to help explain.

3 Where on the ride did you feel you were going the fastest? Why?

- 4** Where on the ride did you feel like you were lifted off your seat? How did the ride cause that feeling?

- 5** Draw a free body diagram labeling the forces acting on you at the top and bottom of the first hill. Is the net force greater or less than normal in these places?

calculations

C. Quantitative Calculations

- 1** Average speed of train for total ride (show work):

_____ m/s
_____ km/h

- 2** Speed at top of first hill (show work):

_____ m/s
_____ km/h

- 3** Speed at bottom of first hill (show work using kinematics):

_____ m/s
_____ km/h

- 4** Calculate the acceleration of the train during the trip down the first hill.

_____ m/s²

- 5** Use potential and kinetic energy relationships to determine the speed of the train at the bottom of the first hill.

_____ m/s

- 6** Compare answers #3 & #5 and explain the results.

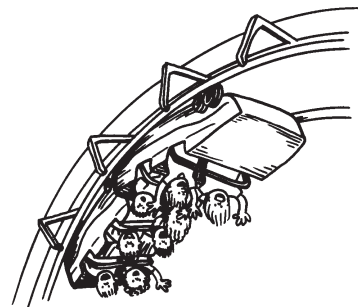
Corkscrew

A. Data

Length of track 702m

Measurements while standing in line:

- (a) height of first hill _____ m
- (b) approximate length of first drop _____ m
- (c) time for first drop _____ s
- (d) time for entire ride _____ s



Measurements while on ride: (using accelerometer)

Maximum **g** _____ g's at _____ (location)

Minimum **g** _____ g's at _____ (location)

g forces at bottom of hill: _____ g's

g forces in the loop: _____ g's

Measurements from observation area: (Collect data you need to answer the questions)

Time for length of train to pass point at top of first hill _____ s

Approximate length of first drop _____ m

Time for first drop _____ s

Time for length of train to pass point at bottom of first hill _____ s

Time for length of train to pass point in loop section of ride _____ s

Radius of loop _____ m

B. Qualitative Tasks

- 1 What sensations do you feel in the curves of the loop section of the ride?

- 2 Where is the highest point of the ride? Why is it there?

- 3 Where on the ride did you feel you were going the fastest? Why?

- 4 How do your feelings in #3 compare with the results in the calculations section?

- 5 Where was there negative acceleration during the ride?

calculations

C. Quantitative Calculations

- 1 Average speed of train for total ride (show work):

_____ m/s

_____ km/h

- 2 Speed at top of first hill (show work):

_____ m/s

_____ km/h

- 3 Speed at bottom of first hill (show work, using kinematics):

_____ m/s

_____ km/h

- 4 Calculate the acceleration of the train during the roll down the hill.

_____ m/s²

- 5 Use potential and kinetic energy relationships to determine the speed of the train at the bottom of the first hill.

_____ m/s

- 6 Compare answers #3 and #5 and explain the results.

Hellevator

A. Data

- 1 Height of tower _____ m
- 2 Height of riders at top of flight _____ m
- 3 Mass of riders (estimated) _____ kg
- 4 Time of ride up _____ s
- 5 Time of ride down (freefall) _____ s
- 6 Measure the forces:
 - during ride up _____ g
 - at top of ride _____ g
 - during ride down _____ g
 - at bottom of ride _____ g

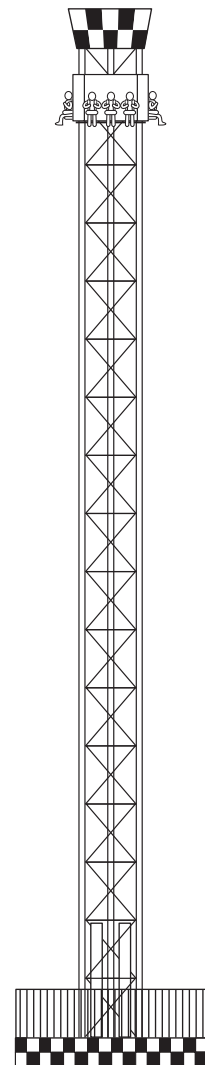
B. Qualitative Tasks

- 1 Have the riders take their pulse rate:
 - (a) before they get on this ride. _____
 - (b) immediately after they have finished this ride. _____
 - (c) Explain any changes. _____

- 2 In a few words, have the riders describe how they felt:
 - (a) before the ride started _____
 - (b) at the highest point of the ride _____
 - (c) during free fall _____
 - (d) at the end of the ride _____

- 3 Where on the ride do riders experience:
 - (a) more gs than normal _____
 - (b) less gs than normal _____

- 4 Explain the riders' sensations and the gs they felt in #3 in terms of the physics of the ride.



calculations

C. Quantitative Tasks

- ❶ Calculate the average velocity as the riders travel up the ride in m/s.

_____ m/s

- ❷ Calculate the final velocity the riders reach at the end of their free fall in m/s.

_____ m/s

- ❸ Calculate the initial velocity of the ride needed to propel it to its maximum height.

_____ m/s

- ❹ If the acceleration up the tower happens during the first 5 meters, what is the acceleration during this time?

_____ m/s^2

_____ g's

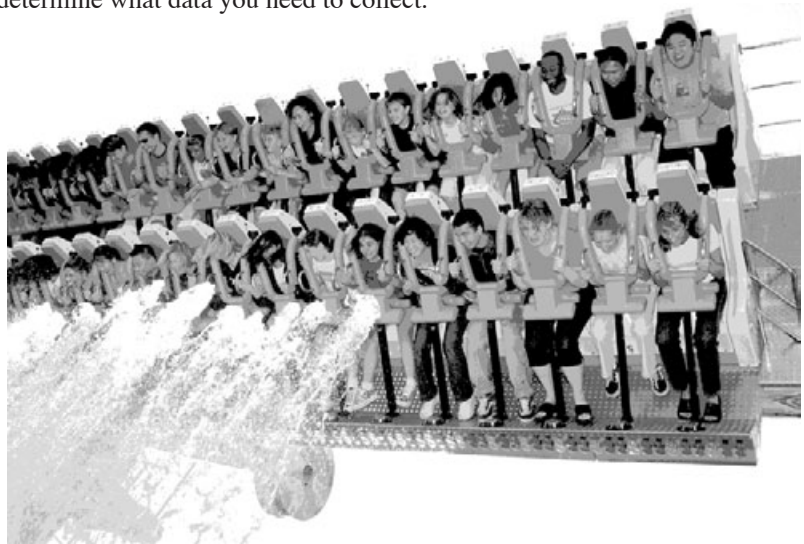
- ❺ Use the acceleration found in #4 above to calculate the force necessary to achieve the acceleration.

_____ N

Hell's Gate

Stand in a position where you can observe the ride. Take data and answer the following questions. After reading the questions, you must determine what data you need to collect.

A. Data



Measurements while on ride: (using accelerometer)

Maximum **g** _____ g's at _____ (location)

Minimum **g** _____ g's at _____ (location)

B. Qualitative Tasks

1 Have the riders take their pulse rate:

- (a) before they get on this ride. _____
- (b) immediately after they have finished this ride. _____

2 In a few words, have the riders describe how they felt:

- (a) before the ride started _____
- (b) during the ride _____
- (c) after the ride ended _____

3 Where on the ride do the riders experience:

- (a) more g's than normal _____
- (b) less g's than normal _____

- 4 Explain the riders' sensations and the g's they felt in #3 in terms of the physics of the ride.

calculations

C. Quantitative Tasks

- 1 Calculate the average speed during the ride in m/s.

_____ m/s

- 2 Estimate the mass of the ride and the riders.

_____ kg

- 3 Calculate the amount of work necessary to move the ride and the riders from the lowest point to the highest point on the ride.

_____ Joules

- 4 How much power do the motors have to supply to move the ride and the riders in calculation #3?

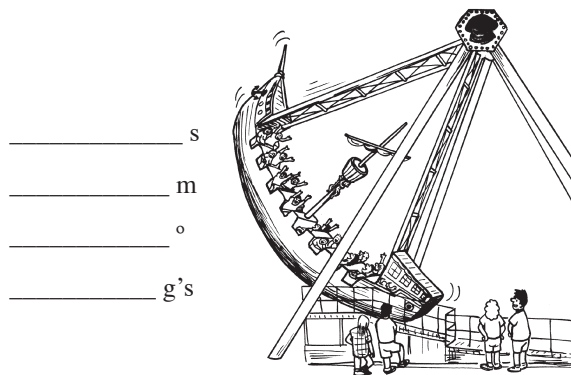
_____ kW

- 5 Present data and calculations to show why your maximum g measurement was accurate.

Pirate

A. Data

- 1 Time for one period (complete cycle)
- 2 Estimated radius of the ship's path
- 3 Maximum angle of displacement
- 4 Maximum accelerometer reading



B. Qualitative Tasks

- 1 Consider the rocking boat described above as a pendulum. In a simple pendulum, the mass is considered to be concentrated at the end of a weightless string.

A simple pendulum at small displacements exhibits simple harmonic motion with the period t of the pendulum's swing expressed by the following relationship:

$$t = 2\pi \sqrt{\frac{L}{g}} \quad \text{Where } L = \text{the length of the pendulum's string.}$$

Calculate the period of the Pirate if it were a pendulum.

_____ s

- 2 From your results above, decide if the boat is a simple pendulum. Why or why not?

- 3 In each arc, where did you feel:

a) the strongest push against your back?

b) the most pressure against your seat?

c) the least pressure against your seat?

- 4 When did you feel you were going the fastest?

- 5** If you have a vertical accelerometer, hold it in front of you during the ride. Observe the motion of the suspended mass.
- a) In what part of the ride was the mass pulled farthest down the tube?

- b) In general, describe the motion of the suspended mass during an arc and during a loop.

calculations

C. Quantitative Calculations

- 1** Calculate the distance of the ship's arc.

_____m

- 2** Calculate the ship's average speed in the arc.

a) _____m/s

b) _____km/h

- 3** Calculate the average centripetal acceleration experienced in the loop.
Include your unit label.

- 4** Express the answer to #3 above in g's.

_____ g

Waterfall

Stand in a position where you can see the final drop of both rides, take data and answer the following questions. Some data will be provided, some will not. After reading the questions, you must determine what data you need to collect.

A. Data



B. Qualitative Tasks

- 1 Look at the place where each boat begins its final drop. What can you say about the vertical height of each of these? Is one higher than the other, or are they both about the same height?

- 2 According to your answer to the last question and considering the data which is supplied, what can you say about the potential energy of each boat when they have people of roughly the same weight?

- 3 As you watch the boats make their drop, do you notice any difference in the path that each takes to the bottom?

- 4 When each boat gets to the bottom of the run, what has happened to the potential energy each one had at the top?

- 5 Does the amount of potential energy each loses depend on the path each one takes to the bottom? Explain why or why not.

- 6 Considering everything you've answered so far, what would you expect to be true of the final velocity of each boat? Is one higher than the other or are they the same?

- 7 If you put more people into a boat (thus increasing the mass) would you notice any difference in the final speed?

calculations

C. Quantitative Calculations

- 1** Look at the place where each boat begins its final drop. Determine the vertical distance of this drop for each boat using any method you prefer. Is one higher than the other, or are they both about the same height? Show work or describe method for credit.

- 2** Using potential and kinetic energy relationships, calculate the theoretical maximum speed at the end of the final drop for each ride (assume no energy loss). Before you complain that this is too much work, think about it: will the different path each ride takes to the bottom affect the final speed? Show work for full credit.

- 3** Go to a place where you can see the end of each ride. Calculate the final speed using the marked distances (see Data section). Should the speeds agree? Show work for full credit. Assume zero velocity at the top.

- 4** Do the results of #2 and #3 agree? List two reasons why they might not.

- 5** You have calculated the theoretical maximum speed at the bottom of the hill (#2) and you have measured the actual speed at the bottom of the hill (#3). Now select one of the hills and calculate the percent of energy that was at the top of the drop which was lost to friction during the drop. Assume the boat began from rest.

Extra for Experts: Do the same calculations as above but consider the boat's kinetic energy before making the final drop.

Crazy Beach Party

A. Data

Length of pendulum arm _____ m

Radius of seat rotation _____ m

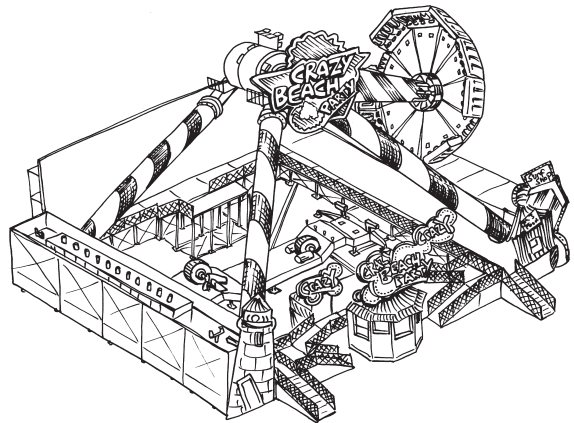
Time for one pendulum swing _____ s

Time for one seat rotation _____ s

Acceleration reading during pendulum swing _____ g's

Acceleration reading during seat rotation _____ g's

of degrees the pendulum moves through _____ °



B. Qualitative Tasks

- 1 What forces do you feel as the ride first starts to swing back and forth? Explain how the ride creates them.

- 2 What forces to you feel as the ride begins to rotate? Explain how the ride creates them.

- 3 Describe your feelings when the ride is moving its fastest with both the pendulum swing and rotation.

- 4 What happens on the ride to cause the feelings in question #3? Use physics terms to describe this.

- 5 How does your pulse rate change from the time before the ride first starts to after it reaches full speed and then ends?

calculations

C. Quantitative Tasks

- ❶ Calculate the centripetal acceleration of the ride while it rotates.

_____ m/s^2

- ❷ Calculate the centripetal acceleration of the pendulum part of the ride.

_____ m/s^2

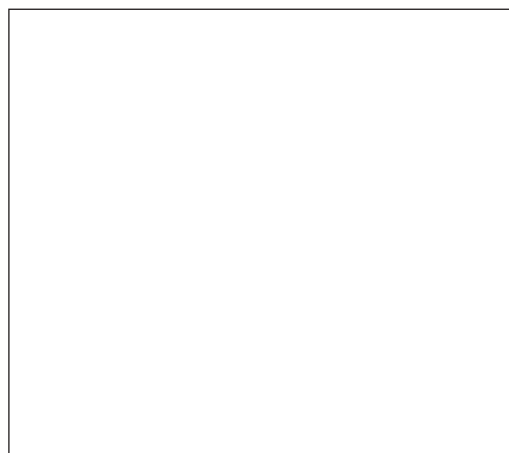
- ❸ Combine the results from questions 3 and 4 above to determine the net acceleration at the lowest point on the ride.

_____ m/s^2

Break Dance

A. Data

- ① Length of time for complete ride _____ s
- ② Length of time for one primary rotation on the ride _____ s
- ③ Number of secondary rotations in one primary rotation _____
- ④ Diameter of the ride _____ m
- ⑤ Diameter of secondary rotation _____ m
- ⑥ g force readings using a lateral accelerometer:
 - minimum reading while the ride is moving _____ g's
 - maximum reading while the ride is moving _____ g's
- ⑦ Mass of the rider _____ kg
- ⑧ Concentrate your attention on one rider during the ride and follow this single rider's path for at least one full revolution of the ride. In the box at the right, draw a diagram of the path he took for that single revolution. (Your diagram should be what you would see if you watched the rider's path while looking down on the ride from above.)



B. Qualitative Tasks

- ① Does the primary rotation on this ride turn clockwise or counter-clockwise?

- ② What direction(s) does the secondary rotation on this ride turn? If it turns different directions, keep track of the direction of the turns for one full ride.
 Spins clockwise: _____ Doesn't spin: _____ Spins counter-clockwise: _____
- ③ Explain the rider sensations and the g's they felt due to the results in question 2 and the physics of the ride.

calculations

C. Quantitative Tasks

- 1 Calculate the average velocity of the ride.

_____ m/s

- 2 Calculate the average centripetal acceleration and centripetal force the rider feels due to the primary rotation of the ride.

_____ m/s^2

_____ N

- 3 Calculate the average centripetal acceleration and centripetal force the rider feels due to the secondary rotation of the ride.

_____ m/s^2

_____ N

- 4 Calculate the net centripetal force and net centripetal acceleration due to your results from questions #2 and #3. How do these values compare to your accelerometer readings. Explain any differences.

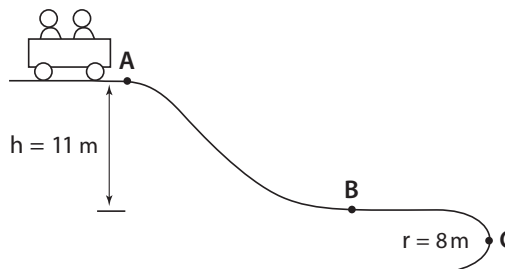
- 5 Draw a vector diagram for different places on the ride and use it to explain the physics of the ride and the sensations you feel.

Physics 12 Quiz

A roller coaster-type ride begins at the top of an 11 metre hill. After going down the hill, the cars make a lateral circle with a radius of 8 metres. The data below was collected on this ride.

Data

Train Length	=	10.5 m
Time to pass point A	=	2.1 s
Time to pass point B	=	0.7 s
Height of hill	=	11 m
Radius of lateral circle	=	8 m



- 1 Calculate the velocity of the car at point A.

_____ m/s

- 2 Calculate the velocity of the car at point B.

_____ m/s

- 3 Use the energy relationship ($E_p + E_k$) to calculate the velocity at point B.

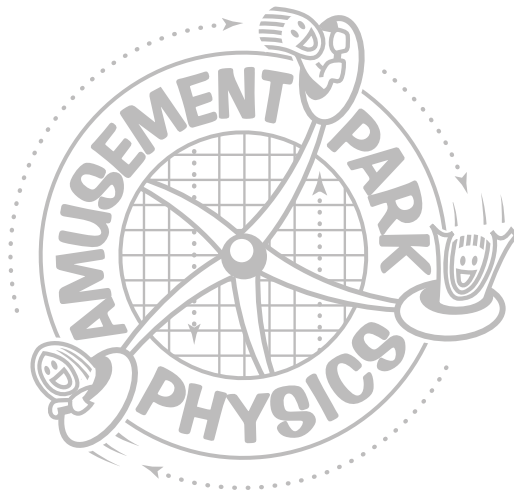
_____ m/s

- 4 Compare answers #2 and #3 above and explain any differences.

- 5 Calculate the centripetal acceleration at point C.

_____ m/s

- 6 Calculate the bank of the track at point C to ensure no lateral acceleration occurs.
Show your work and a vector diagram.



Section E

Make-Up Assignments

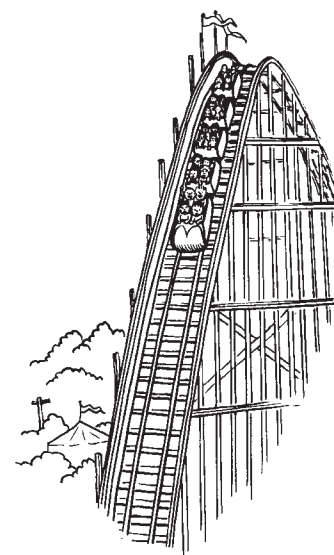
page E-1 Coaster Calculations

page E-2 Klothoid Loop

Coaster Calculations

The following data pertains to the **American Eagle** coaster near Chicago, Illinois.
Use the data table to work the problems listed below.

Data	Track length	= 1417 m
	Train mass	= 4536 kg
	Greatest height	= 38.7 m (first incline)
	Length of 1st vertical drop	= 44.8 m
	Angle of 1st drop	= 55°
	Length of 1st lift	= 100 m (chain speed: 2.7 m/s)
	Maximum speed	= 106.7 km/h
	Length of ride	= 2 min, 23 s
	Gravity forces	= Up to 1.65 g's in the dips ($1\text{ g} = 9.8\text{ m/s}^2$)

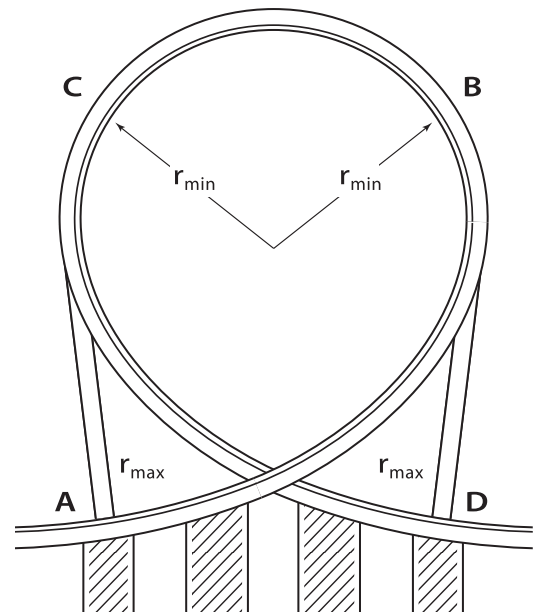


- 1 How long does it take for the coaster to climb the first hill?
- 2 What is the climbing angle of the first incline?
- 3 What is the maximum gravitational potential energy for the coaster as measured above the lowest point in the ride?
- 4 What is the average speed of the entire ride?
- 5 What is the maximum kinetic energy for the coaster?
- 6 Assume a speed at the top of the 1st hill of 2.7 m/s and a vertical drop of 44.8 m. What should be the speed at the bottom of the hill with no friction or air resistance losses?
- 7 How large are the actual friction and air resistance losses in km/h?
- 8 How long is the track down the first drop?
- 9 What is the friction and air resistance loss per metre during the drop?
- 10 If the coaster had the same frictional and air resistance losses for the whole trip, would it reach the station?
- 11 Do you expect friction/air resistance losses to be greater or less in the latter part of the ride? Explain.

The Klothoid Loop

A Klothoid loop has an ever decreasing radius as the rider enters the loop at point **A** and climbs to point **B**. From point **B** to point **C** the loop is circular, with constant radius. At point **C** the radius begins to increase until it reaches its maximum value again at point **D**.

- 1** What is the advantage of this curve over a circular loop?

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and extend across the width of the page. There are no margins, text, or other markings on the paper.

- 2** Assume a coaster speed of 96.5 km/h as the centre of the coaster enters the loop, a loop height of 23.16 m, and a uniform decreasing radius of curvature from 49 metres to 7 metres with a circular top loop of 130.6°. Next assume a frictionless track and calculate the velocity as the middle of the coaster passes: (a) Point **A**, (b) Point **B**, and (c) Point **C**.

a) _____

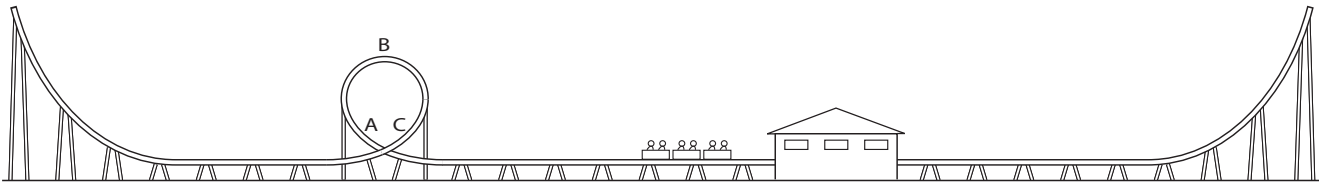
b) _____

c) _____

The picture below illustrates a Shuttle Loop Coaster which uses a Klothoid loop.

The coaster carries riders through the loop forward and then backward. A slingshot flywheel catapult mechanism propels the coaster along the track.

The coaster makes the loop going forward and climbs the left ramp. The coaster then rolls down the ramp, through the loop backward, and up the right ramp. In just over 30 seconds, the coaster is back at rest in the station.



Accelerometers mounted in the front and rear cars measure the force component perpendicular to the rider’s seat. The table below gives the data recorded. Use it in answering the following questions:

Accelerometer Data
Going Forward and Backward Through Loop

Entering loop forward	(Point A)	=	4.8g (front car)	3.4g (back car)
Top of loop forward	(Point B)	=	1.5g (front car)	1.4g (back car)
Exit of loop forward	(Point C)	=	3.2g (front car)	4.8g (back car)
Entering loop backward	(Point C)	=	2.6g (front car)	4.2g (back car)
Top of loop backward	(Point B)	=	0.5g (front car)	0.3g (back car)
Exit of loop backward	(Point A)	=	4.2g (front car)	2.8g (back car)

3 Explain differences in accelerometer readings for the front and back cars at Point A going forward and backward.

4 Explain why the g-force is less at the loop top when the coaster goes through the loop backward.
